VEHICULAR AD HOC NETWORKS ROUTING PROTOCOLS: SURVEY

Kashif Naseer Qureshi, Abdul Hanan Abdullah, Fasee Ullah
Faculty of Computing, Universiti Teknologi Malaysia, Skudai, Malaysia
E-mail: kashifnq@gmail.com, hananfsksm@gmail.com , faseekhan@gmail.com

ABSTRACT: *Vehicular ad hoc networks are expected to support a large spectrum of applications in the field of intelligent transportation systems. It is an emerging and boosting field to provide wireless communication among vehicles. VANET has some unique and special characteristics compared with traditional mobile ad hoc networks such as self-organization, high mobility, dynamic and frequent changing topologies. Traditional routing protocols have been suffered to deal with these characteristics in terms of data delivery, network overhead. In order to overcome these issues, there is a need for efficient routing protocols to deal with route break, disconnectivity and data delay issues in the network. Various different types of protocols have been proposed for vehicular ad hoc networks but still they have some limitations and routing issues in the network. In this review, we examined the recent and well-known routing protocols for VANET, their types, functions with different issues and challenges in the network***.**

Keywords: *Routing, VANET, Geographical, Topology, Mobility*

1. INTRODUCTION

In Vehicular Ad-hoc Networks (VANETs), the moving and fixed vehicle nodes are communicating with or without permanent infrastructure with each other. The communications between vehicles are based on single and multi-hop communication with the help of different wireless technologies and standards. Recently, the VANET is a dominant technology in the transportation sector, where various projects have been proposed for dynamic cooperative networks in order to provide road safety and eco-friendly driving experience such as Networks on Wheels (NoW), CarTALK 2000, SAFEPOT, and eCoMove [1, 2]. VANET has some unique features to distinguish it with other traditional Mobile Ad-hoc Networks (MANETs), such as high mobility and frequently changing topologies. However, it has some features, which are similar with MANET such as self-organization and management and required low bandwidth for data communication [3]. The vehicle nodes are operational by On Board Units (OBUs), Sensors, Roadside Units (RSUs) and other communication devices. Basically, VANET has two types of applications safety and infotainment. The safety applications are based on real time and critical messages like accident detection, warning and disaster messages, these messages need more priority. On the other hand, in infotainment applications, internet, video and voice chatting, advertisement services are included. To make the communication possible in these applications, different types of routing protocols have been proposed for data forwarding.

Due to high mobility environment, VANET has various routing issues and challenges such as network delay, inefficient delivery ratio, and computational complexities in network. To deal with these issues network need efficient and intelligent routing protocol for data forwarding. In this context, we review the most popular routing protocols in the field of VANET and discusses their limitations. In addition, the issues in these routing protocols and qualitative comparison is also presented.

The rest of paper is organized as follows: Section 2 presents a detail overview of VANET. Section 3 illustrates the recent challenges. The most popular VANET routing protocols are describes in Section 4. Section 5 presents mobility models and discussion is in Section6. Paper is concluded in Section 7.

2. OVERVIEW OF VANET TECHNOLOGY

The VANETs network architecture is divided into three main types: cellular or Wide Local Area Network (WLAN), pure ad hoc and hybrid. The cellular or WLAN category is based on permanent cellular gateway including wide range access points or base stations. These gateways are installed at the junctions or at the road side and connected with internet for gathering and sending the data packets. This type of communication also called vehicle-to-infrastructure (V2I) communication and used for infotainment, web browsing and parking information applications [4]. This category need expensive infrastructure and has deployment issues in network. Local area network (LAN), Dedicated Short Range Communication (DSRC) and some other heterogeneous wireless technologies such as IEEE 802.11, 16e, 3G, LTE and Advance LTE are the most considerable technologies used in V2I communications [5]. The second category is pure ad hoc or vehicle-to-vehicle (V2V) network, where vehicle nodes are communicating without any infrastructure. This category is self-organized and has limited communication range and convenient for emergencies situations such as alerting the vehicles about accident and assisting the police to tracing criminals [6]. The last type is hybrid network, which is combination of cellular and ad hoc networks [7]. The most popular applications in this category are screening, security, entertainment and file sharing.

The VANET system architecture components are on board unit (OBU) application unit (AU) and roadside unit (RSU). The RSU connects with internet and provide services to OBU, which is installed in vehicles for collecting and processing the data. The RSU is fixed along the roadside and redistributing the information between other RSUs and OBUs. The low bridge warning application, accident detection applications, are most popular applications based on RSUs. The communication between RSU and OBU is possible by family of standards Wireless Access in Vehicular Environments (WAVE). In addition, the OBU carries the AU, which is responsible for running applications and make connection between OBU and RSU. The AU is dedicated for safety applications and just like Personal Digital Assistant (PDA) device.

3. VANET CHALLENGES

The VANET communication is different with traditional MANET due to high mobility, self-organizing network,

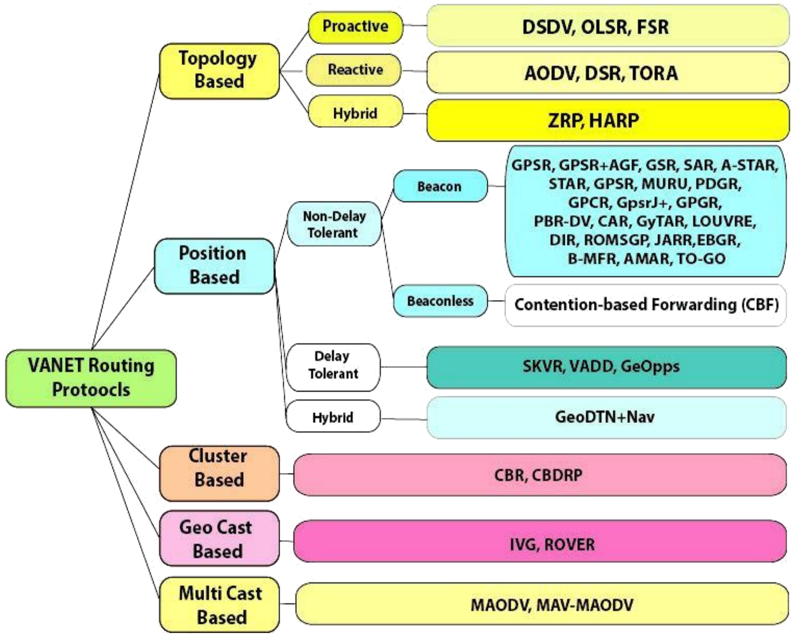

Figure 1. Taxonomy of VANET routing Protocols

dynamic topologies, limited wireless range and less bandwidth environment [8]. These characteristics predicate different effects on routing protocols and communication systems and cause of disconnectivity, route breakage, and attenuation issues. The testing of routing protocols depend on different mobility and prediction models, which are limited with roads layout, streets, and pre build highways. It is bit difficult to test these protocols in real scenarios. Another challenge is existing of different obstacles in the city environment and a major cause of packet loss, disconnectivity, interference and data delay in network because they disturb the broadcasting and radio signals in network. The deployment of infrastructure is another challenge because of its cost and less coverage. The real time applications require data delivery in time with high priority. The data delay and disconnectivity in network may cause of serious results in the shape of accidents. Some other factors are also exist behind these failures such as security attacks and slow data sending processes [9].

4. ROUTING PROTOCOLS

History of VANET routing protocols was started from MANET protocols [8]. However, due to unique characteristics of VANET, it requires a smart and efficient routing protocols to maximizing throughput, control network overhead and minimize packet loss. The routing strategies have been defined based on VANET architecture and nature of applications. Basically, in this survey the VANET routing protocols are categorized into main fine groups: topology, position, cluster, geo-cast and multicast based protocols. In this section, we discusses these protocols in detail and their limitations in network.

4.1 Topology-Based Protocols

The topology-based routing protocols utilize link information and dynamically initiate routing decisions in the network for packet forwarding. In addition, these protocols require extra topology information for forwarding decisions and processes. These routing protocols further divided into proactive, reactive and hybrid categories.

4.1.1 PROACTIVE PROTOCOLS

Proactive protocols broadcast periodic hello messages and maintain routing tables for representing the topology in network, and based on shortest path algorithm. Due to regular update of routing tables, these protocols utilize more bandwidth especially in dense environment. Furthermore, the routing tables update on regular basis and whenever topology will change, the nodes renew their routing tables. There are two types of routing updates in these protocols: periodic and triggered [10]. Whenever, the new node add in network, the entry of this node store and update in other nodes tables and table size increases with network overhead. To address this issue, the two routing protocols were proposed: Destination Sequenced Distance Vector (DSDV) and Fisheye State Routing (FSR). Proactive protocols are not feasible for broad network due to its regular updating mechanism in the shape of routing tables. Although, these protocols are much better in real time applications such as in delay sensitive services [11].

1) Destination Sequence Distance Vector Routing (DSDV)

The DSDV algorithm was developed in 1994 [12], and addressed the routing loop issue for mobile computers. The protocol uses Bellan-Ford algorithm for certain improvements. The protocol creates loop free available routes from single source to destination, and uses distance vector and shortest path algorithm. In network, each node maintains information for all their probable destinations and number of required hops within the network in a table, as shows in Figure 2 [13].

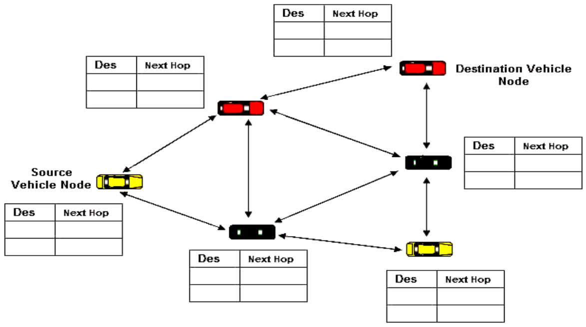

Figure 2. Proactive topology-based routing protocols route establishment

For decreasing the network traffic, protocol determines two sequential steps: incremental and full dump. The full dump, routing information sends to all accessible nodes. On the other hand, in incremental step, the packets sends when there is any changing in route. However, due to these two steps the nodes interact with each other and partially routing tables are updated with its neighbors. Furthermore, in full dump packets, the network bandwidth decreases and in incremental type the network overhead increases. DSDV protocol is not suitable for large networks due to its bandwidth and updating procedures [14].

2) Optimized Link State Routing Protocols (OLSR)

Optimized Link State Routing Protocols (OLSR) is table driven, point-to-point, or proactive routing protocol based on regular information exchange mechanism among nodes. Protocol uses a procedure called Multi-Point Relaying (MPR) [15] for optimize the messages and initiate flooding process for route setup or route maintenance. The protocol minimizes the number of active relays for covering the neighbors, and known as MPR. The MPR is a proficient method for traffic control by decreasing the quantity of required transmission. OLSR protocol was introduced for route accuracy and stability of data in the network. The Protocol has two key concepts; MPR and Optimized State for covering one-hop and two-hop neighbors or send link state information for route maintenance. Every node receives updates only once, and unselected packets cannot retransmit the updates. Therefore, all routes and destinations are known in network and maintained before the operation. On the other hand, due to high mobility of vehicles the optimal node calculation may be impossible [16]. Figure 3 illustrates the OLSR routing protocol routing process by MPRs.

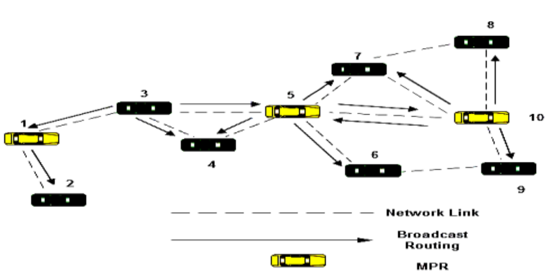

Figure 3. OLSR Routing Protocol Operation

3) Fisheye state routing protocol (FSR)

Fisheye State Routing (FSR) protocol was developed in [17], based on efficient link state or proactive state. The FSR protocol sustains the overall knowledge of the network topology in table for every node and update the network information with neighbor nodes instead of the whole network. During the exchange process, the bigger sequence numbers swap with smaller sequence numbers. The updates of link state information vary with the destination distance. It is scalable for large network and reduces the update messages size, but due to scalability, the accuracy is not sufficient and routing table size increases. In FSR, the route discovery unsuccessful when the destination is not in the range of source node. Figure 4 shows the basic operation of FSR with the center node. The FSR protocol located in center with specified information of the nearest nodes in the green circle and have no correct information about remote nodes, but still it is working correctly due to route information turn into more correctly as the packet near with destination.

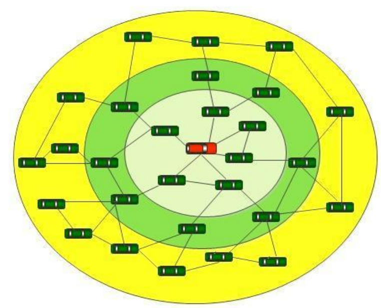

Figure 4. Operation and Accuracy in FSR protocol

4.1.2 Reactive (on-demand) Routing

Reactive protocols are opposite to proactive protocols. Whenever network topology changes, these protocols do not maintain routing tables. In these types of protocols, the query floods into the network, while a source node needs to transmit the data. Furthermore, the discovered route is stored and awaiting for other node, which are unreachable. They are dealing with cache routes and handle the route replies. However, due to route discovery mechanism the network bandwidth is low. Dynamic Source Routing (DSR) and Ad-hoc On-Demand Distance Vector routing (AODV) are popular routing protocols in this category. Figure 5 shows the basic routing process of reactive protocols.

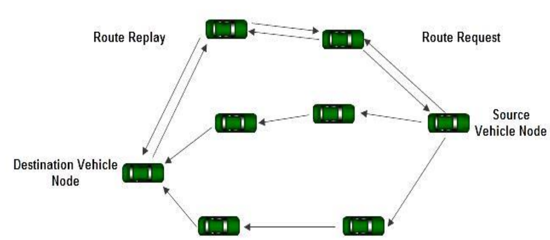

Figure 5. Reactive Route Establishment

1) Ad hoc On-Demand Distance Vector routing (AODV)

The (AODV) was proposed in [18] as a topology based protocol. AODV reduces the number of messages due to it's pure on demand or need based mechanism. Protocol maintains all the listed routes in the table. The AODV protocol is the refinement of DSDV and DSR algorithms. In AODV, the source node initiates discovery with Hello beacons to check its neighbors, after this process source node transmits a Route Request Packet (RREQ), and then the neighbor nodes repeat same procedure with their neighbors. The RREQ packets do not know about route toward the destination before sending to their neighbors. The RREQ messages have IP addresses of source, destination, current node and last known sequence numbers. When RREQ packet reaches to destination node, it adds the address entry in their routing table, this process is called backward learning.

Finally, when data packet reaches to the destination by backward learning then a Reply Packet (RREP) transmits to the source node as shows in Figure 6. The AODV protocol performance is greater in terms of routing overhead, packet delivery ratio [19]. However, protocol uses periodic beaconing messages, which leads to utilize extra bandwidth. Various types of on demand distance routing protocols have been proposed such as AOMDV, S-AOMDV, and RAOMDV, SD-OMDV.

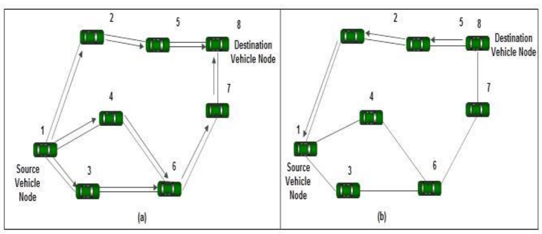

Figure 6. (a) Transmission of RREQ packet (b) Transmission of reply packet from destination to source

2) Dynamic Source Routing Protocol (DSR)

The protocol was proposed in 1996 [21], as a straightforward, competent source based routing protocol similar with AODV. The DSR forms the route on demand as a substitute of routing table. In source based routing, the packet header contains list of sequence numbers of nodes for transmission. The protocol has two processes: route discovery and maintenance. In discovery process, DSR sends data to the target node and check cache for existence of a route and if the route entry does not exist then it starts the discovery phase. On the other hand in maintenance phase, if source node notices any broken route then divert it to other known route towards the destination. The DSR protocol has some limitations in terms route failure in maintenance process due to high mobility of vehicles in network. Another limitation is scalability, which affects the protocol performance [20].

3) Temporally Ordered Routing Algorithm (TORA)

The TORA protocol was proposed in [21] based on link reversal on demand routing algorithm. The protocol was designed for discovering the routes on demand and multiple routes towards the destination, establish routes quickly, and minimize communication overhead. TORA works on limited control message propagation in the extremely dynamic ad-hoc networks. In TORA, source node initiates a query to forward data between source and destination. TORA maintains the route and whenever the route is no longer valid or available it erase from its table. TORA uses three types of messages: QRY for creation, UPD for maintenance and creation, and CLR for erasing the route. Protocol minimizes the communication overhead when the topology change and feasible for dynamic ad-hoc networks. TORA performance is better than DSR in network [24].

4.1.3 Hybrid routing

The hybrid protocols are based on reactive and proactive protocols characteristics. The reactive approach is used to protect and provide more accurate information to the local scope, whereas the proactive is used for distance routing. These protocols are zone based, where zones are divided into diverse zones for routing, maintenance, and discovery. The best-known hybrid protocols are ZRP and HARP.

1) Zone Routing Protocol (ZRP)

The Zone Routing Protocol (ZRP) [22] is a hybrid algorithm, it separates the network into groups of nodes as well as intersecting zones, which are in a radius of the zone. The interaction of nodes overcome the delay and network overhead for discovering the route. The nodes divide into zone distinct and overlapping zones, where the group of nodes are in zone radius. The zones create by hop distance and select through topological distribution. The border node of every zone refers to peripheral node. The function of peripheral nodes is routing and discovering the outside zone by reactive Inter-zone routing protocol (IERP) approach. On the other hand, proactive approach uses for within the zone as Intra-zone Routing Protocol (IARP).

2) Hybrid Ad Hoc Routing Protocol (HARP)

HARP protocol was proposed in 2001 [23] based on proactive and reactive approaches. The protocol divides the network into non-overlapping regions and recognized a steady route between source and destination. This operation uses for improve the network delay issue. The HARP selects the best route by discovering the zones and depend on the constancy features. The protocol works with intra-zone and inter-zone, which are reactive and proactive protocols.

4.1.4 Analysis and Evaluation of the Topology-based Routing Protocols

For providing reliable and efficient communication in VANET, the routing protocols have been studied in various ways. These naive mechanisms waste bandwidth and increase network delay due to high mobility patterns, demographics, density of vehicles, and rapid changing topologies. In VANET environment, the massive number of vehicles are exchanging the information in urban and highway scenarios. The topology based routing protocols are less suitable for a vehicular environment due to their topology information exchange mechanism [24].

The proactive type in topology based routing protocols maintain and bring up to date information of routing with periodically updates. The VANET topologies are changing regularly due to update and utilize more bandwidth in network. On the other hand, the reactive type protocols are based on demand and mostly best for application scenarios. In addition, the hybrid routing protocols are efficient compare to single reactive and proactive due to their mix reactive and proactive features, where network divided into zones for route maintenance and discovery. The hybrid protocols are best to reducing the network overhead and delay, but still these protocols have some issues. The network size rely on a restricted number of nodes and VANET nature is highly dynamic [22].

In the light of the aforementioned discussion, the topology based routing protocols are less preferable to deal with vehicular environment.

4.2 Position-based routing protocols

The position or geographical-based routing protocols are working with their own and neighbor location through GPS and digital map devices. The nodes do not manage routing tables or information of link state with their neighbor nodes like in topology based reactive and proactive routing protocols. According to different research on VANET routing [25-27], the overall functions of position based routing protocols are better to handle the highly dynamic VANET environment compared to topology based routing protocols.

Position based routing protocols are classified on different routing factors and separated into three main categories: Non-delay Tolerant Networks (Non-DTN), Tolerant Networks (DTN) and hybrid. Non-DTN or (Non-Packet Buffering) protocols do not consider disconnectivity of platoons of vehicles whereas the second category DTN or (Packet Buffering) category includes those routing protocols which consider intermittent connectivity. The third category is hybrid in geographical routing protocols, where protocols combine Non-DTN and DTN features for handle uneven distribution of vehicles. In the following sections, these three sub-categories are explained in detail.

4.2.1 Routing Protocols Strategies

The routing strategies of position based routing protocols depend on the information of geographical location of the vehicles. The nodes are selecting the greatest path for onward the data towards the destination without using IP addresses for identifying the routes. The position based routing protocols split into three characteristics forwarding, path selection and recovery.

a) Path Selection

The path selection is not mandatory for routing protocols, but if protocols utilize path selection so it is an advantage. In the urban environment, the availability of paths are high due to traffic density. The well-known algorithm Dijkstra uses for path selection in VANET. In this algorithm, the path between sender and receiver nodes are calculated with junctions by the graph edges and called path-using Dijkstra.

b) Forwarding Strategies

Forwarding strategy is must for onward the packets to the destination in position protocols. For forwarding, the most well-known approaches are greedy forwarding, greedy along the path strategy, restricted greedy and recovery mode strategies. In the greedy approach, the packet forwards to the node, which is near with destination. When any type of path is used, it referred to greedy along the path approach. It is same like greedy approach, but a little difference is that the nodes are present in the next junction and on the selected path. Restricted greedy method is bottleneck in communication because it mitigates the propagation problem in junctions. The communication is not traversing because of corners plus obstacles and base on the presence of a precedence node which is in the center of junction. The improved greedy strategy is to forward the packets when vehicle travelling toward the destination.

c) Recovery Strategy

The recovery-mode or strategy adopts right hand rule to traverse graphs. When the forwarding node is near to the destination node, the algorithm switches back and node triggers the recovery strategy. Most of the routing protocols utilizes recovery strategy in local maximum and minimum cases.

4.2.2 Non-delay Tolerant protocols

In this category, the protocols aim to send data packet between the source and destination. The protocols assume that there are always enough vehicles in urban and highway scenarios and due to this packet carries vehicle nodes and not reach to disconnected networks. The greedy approach of non-delay tolerant protocol is that, where source forwards packet to its neighbors, which is closer to destination node. If the neighbor is not nearer to the destination then packet forwarding may be failed. The non-delay protocols handle this failure with individual recovery approach. These protocols further classified into three groups beacon, beaconless and hybrid.

a) Beacon Protocols

The beaconing approach is used to broadcast short hello messages periodically to announce the presence of a node. Beacon contains vehicle node position, movement, and acceleration in the vicinity. There are many protocols are fall in this category, which are discussed as follows:

1) Greedy Perimeter Stateless Routing (GPSR)

The GPSR was proposed in [28], and has been considered as a novel and benchmark algorithm in VANET. The protocol knows the vehicle position, neighbor and destination position by GPS devices. The protocol depends on greedy and perimeter approaches. In greedy approach, the protocol onwards the data packet to the instant neighbor, which is closer to the destination. The packet might arrives at a local maximum due to partial transmission range, and obstacles such as if node distance is less with its neighbors to destination mean node cannot find the next hop near with destination. To out from the local maximum, protocol determines the second recovery perimeter mode, where protocol targets the nearer node with a destination node to forward the packet. Then data packet returns in reverse order according to the distance from the destination node. This process starts until it arrives at a node whose distance is near to the destination then continue greedy mode.

In Figure. 7 (a) the source vehicle node x wants to forward the data packet to target vehicle node D; in the list of x node, V node is near with destination node D. The greedy advance procedure is continue by nodes 1, 2, 3 and 4 until data packet will reach to the target vehicle node D. The second scenario in Figure 7 (b), the vehicle node X is near with target vehicle node D, but X is a local maximum to D, dotted lines shows the local maximum range. Other two possible paths are available for forwarding the data x-y-z-D and x-w-v-D, in this situation the right hand rule applies. The protocol is not suitable for urban scenario due to large obstacles such as buildings, trees, advertisement boards, traffic lights. Another problem in the protocol is the wrong decision on important intersections.

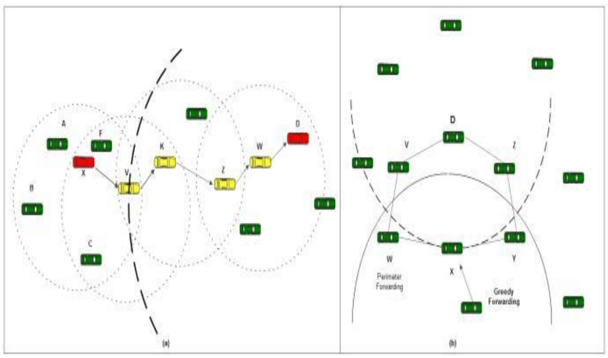

Figure 7. (a) Greedy Approach (b) Perimeter Approach

The protocol contains velocity, direction, and entire travel time information and filters these information from neighbor routing table to the out-of-date nodes. Every forwarding vehicle node can set up the difference of destination actual position and calculate approximately its present location. The result of this process leads to greater data packet delivery ratio compared to GPSR.

2) Advanced Greedy Forwarding (GPSR+AGF)

The GPSR+AGF protocol was proposed in [29] as an enhancement of GPSR. The author observed two issues in GPSR, due to VANET high mobility the routing table is frequently comprised and overcrowded and second issue about position of target and destination node, which is updated in the routing table. When the source node forwards the data packet to destination, the location of the destination save in the routing table, during transmission the destination position changed due to high mobility, and this new information is not updated in the routing table

3) Geographic Source Routing (GSR)

The GSR protocol was presented in [30], for static street maps in an urban scenario. The protocol merges the topological information with position based routing; topological information provides the global knowledge of the city and position based routing provides the destination location. The GSR utilizes the reactive location service (RLS) for obtain the information of the destination. The reactive location service uses for position discovery and a direct translation of the route in a discovery process usually uses in non-geographic or non-position based protocols. Chains of intersections are used to establish the routes toward the destination. The GSR protocol uses less amount of bandwidth and provides high packet delivery ratio. Moreover, GSR does not consider dead-end roads and traffic congestion during rush hours in urban scenarios.

4) Spatially Aware Packet Routing (SAR)

The SAR protocol was proposed in [31], to solve the GPSR and GSR recovery process for keep away from a local maximum. The SAR protocol searches a substitute path from the local maximum location and restores the original route with the new route.

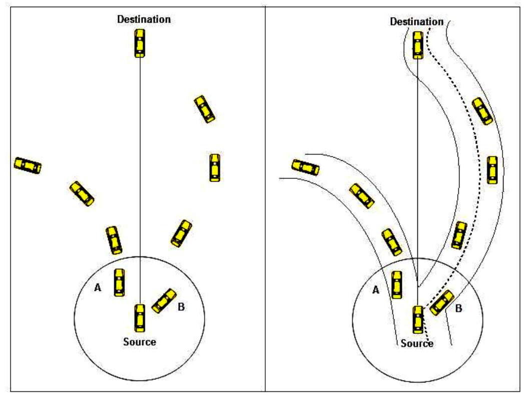

Figure 8. Spatial Awareness in Geographic Forwarding

Figure 8, shows the SAR function, where two vehicles nodes S and D communicate with each other, and use geographic forwarding. The source node S forwards the data to destination node D. The node A is neighbor node of node S, which is nearer to the target node than B. This approach gives the impression that local decision is most advantageous without considering spatial environment.

In same Figure 8, in the second scenario, the node distribution is severely restricted with road formation and the A is situated on the left section, through greedy approach the packet send through many nodes and cause of failure and ultimately recovered. In this case, only right section path is available, then packet has to come back and choose node B and safe from forwarding failure with spatial awareness model. The node B is appropriate neighbor for forwarding the packet to the destination.

The SAR protocol utilizes the source node and set the target node with spatial model and offers ordinary high-level concept for spatial object and their relationship. The spatial model is denoted with a graph G (E, V) to represent spatial information. Which contains a set of vertices, where set V denotes the major places in the map and set E indicates the inner connection between places. The source node calculates the shortest path by Dijkstra algorithm, when the nodes are moving along the edges in the graph from one vertex to another. The source node contains the list of intermediate vertices when sets the GSR to shortest path. The data packets consist of GSR header and when arriving in vertex then removed from GSR and move to the next vertex. Because of this method, the packet travel sequentially nearer to the target node along the GSR from one vertex to the next.

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

The A-STAR algorithm was proposed in [31] for inter vehicular communication in an urban area and handle disconnection problems. The protocol uses the street map for calculate the junctions for data forwarding between source to destination. The calculation of anchor path through traffic awareness is same like GSR protocol. The algorithm uses an opposite approach for connected routes with other vehicles on the road compare with GSR. When we compare A-STAR with GSR and GPSR, the two elements varies. In the first element statistically rated maps such as bus routes in street use to decide the anchor path of optimum connectivity. The traffic awareness concludes and selects an anchor path for packet delivery. The second element is novel local recovery, second strategy is for packets to deal with local minimum in A-STAR. This strategy is more efficient for an urban environment. A-STAR surpasses the GPSR and GSR in performance from the standpoint of traffic awareness.

6) Spatial and Traffic Aware Routing (STAR)

The STAR protocol was illustrated in [32], based on position. When a node wants to send the packet to its neighbor and neighbor node is not existing then the local maximum arises. In this type of scenario, the STAR protocol forwards the packet only for those streets, where vehicular traffic exists. STAR protocol organizes for lower and higher layers. In the lower layer, the information is exchanging about network status and at the higher layer, information uses for computation of paths. So in short, the SAR equally utilizes both spatial and traffic aware street topologies information and overcome the SAR drawbacks.

In addition, the STAR considers the vehicles, which are along the streets for data forwarding. However, the protocol computes packets and route lazily compared with SAR. Further, the protocol is relying on in-between nodes for supply and added the segments of the route and containing partial route in the header. Because of this strategy, the packet header length and route are fixed, which adjusted dynamically with precise movement of the destination and traffic information. The neighbor table has information about location of every neighbor node and updated by beacon messages. The presence vector, persistence vector and neighbor table, are used to decide the traffic low and high density and relate to every node and called dependent data structures. The first presence vector calculates the numbers of neighbor nodes with every cardinal direction and the second persistence vector for detain sparse and dense situation.

Figure 9 illustrates the STAR function, where protocol solves the local maximum problem. The source node send the packet by Dijkstra's algorithm to destination D and computes access point 1 (AP1) and access point 2 (AP2) and send the packet to nearer neighbor to an access point 1 (AP1) (represent as dashed arrow). In the meanwhile a vehicle node move to cross the access point 1 (AP1) and contains a duty to forward the packet to an access point 2 (AP2), although it fails because the neighbor is not present in the suitable direction, so the packet is in a local maximum. The STAR algorithm adopts recovery procedure and calculates new access points (APs) (shows as an empty box) from the present node and utilizes updated traffic information. The new route (shows as black arrow) creates and data forwards.

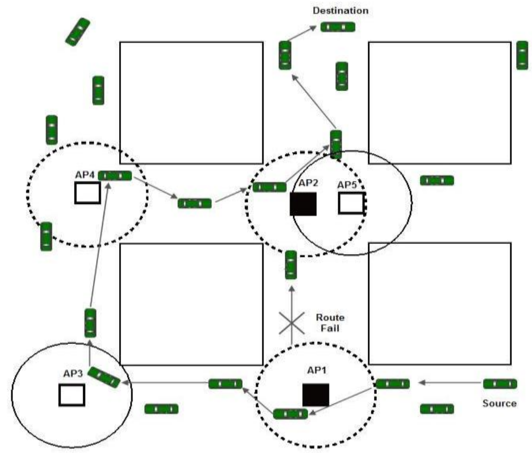

Figure 9. STAR Routing Process

7) Greedy Perimeter Stateless Routing (GPSR)

The GPSR protocol was proposed in [33] for mobile ad-hoc networks (MANETs) and had efficient characteristics such as less packet delay and better data delivery ratio. Further, it uses two approaches for forwarding the packets: perimeter forwarding and greedy forwarding. The nodes in the network have local table and table have all neighbor nodes records with their ID and positions. The source node sends the packet with target node, it is not changeable address. The node enters in the recovery mode when none of the neighbor is nearer to the destination, and called perimeter mode. In perimeter mode, the protocol uses right hand rule and when the node is closer to the destination, protocol return to greedy forwarding and entered in recovery mode.

8) Multi-hop Routing Protocols for Urban Environment (MURU)

The (MURU) protocol [34] is a multi-hop protocol based on some quality factors like speed, trajectories and position of the node and find strong path in the network. The protocol performs better in metropolitan areas and has low overhead and better in packet delivery ratio. MURU introduces a new metric called Expected Disconnection Degree (EDD) for assess candidate path quality. Further, the EDD imitates the probability that a path would break in a convinced time period. EDD computes the vehicle node movement trajectory and speed information and initiates the request message for route discovery. Then, in between mode, protocol estimates link quality and update the present value of path EDD. The destination node finally comes with the smallest probability of broken path. The protocol MURU uses a back off method to decrease the control overhead by suppressing avoidable control messages.

9) Predictive Directional Greedy Routing (PDGR)

The PDGR protocol was proposed in [35], based on directional greedy routing and weighting scores. The protocol calculates the weight by two strategies: direction and position. The first method uses for determine the near node with destination by its position such as in greedy approach and second method is for select a node on the basis of movement toward destination. PDGR protocol utilizes next hop selection through prediction mechanism, however this method is not suitable for all situations. The protocol does not give any surety about packet delivery to the node, especially when the node at the border of transmission range. Protocol still suffers in term of end-to-end delay and packet delivery ratio in network.

10) Greedy Perimeter Coordinator Routing (GPCR)

The GPCR protocol was proposed in [36] for VANET, with self-determination as a digital map feature. The main idea of protocol to gets the advantage from natural planar graph about streets and junctions without any fixed street map. The protocol contains two strategies restricted greedy forwarding and repair strategy. Figure 10 shows the protocol function, where vehicle node A forwards the packet to vehicle node B and node B located on the junction even though the node C cover the radio range of node A, this situation leads to local maximum. The protocol uses restricted greedy approach for data forwarding. The node A is near with node junction, known as coordinator node, and it is continually favors over a non-coordinators to handle the local maximum issue. It uses recovery approach, where the packets are going into reverse greedy mode and finds an alternative answer to returns in the greedy mode. The junction node uses right hand rule for next road segment for forwarding the packet.

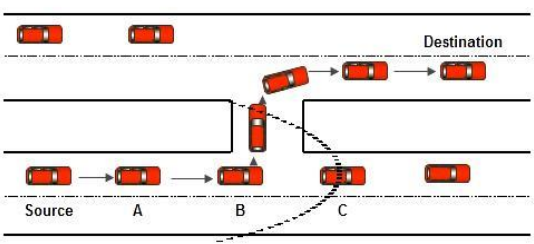

Figure 10. Routing Along Junctions in GPCR

11) GpsrJ+

GpsrJ+ was proposed in [37], to improve the data delivery ratio as an enhancement of GPCR. GpsrJ contains two modes: greedy forwarding and recovery mode. Due to obstacles in urban scenario, the greedy approach is not suitable and need a recovery approach like GPSR uses perimeter strategy for successful delivery. The protocol uses the natural planner feature of street map instead of an expensive planarization. The protocol works to predict the road segment and neighbor junction node for data forwarding.

In Figure 11, the source node forwards the packet to the destination node and avoids the junction area and forward the packet to E. The source neighbors are nodes B, E, where node B sends a beacon message with information of segments R1, R2, R3 and its position as well to the source. Based on road segments the node A receives the message from its neighbors especially about junction neighbors. In right hand rule the packet forwards where its next hop will be form like for node B. The protocol checks, if the neighbor node B is in same road segment where source node present then source node forwards the packet to furthest node E, if it fails then send to junction neighbor node B. The protocol avoids expensive planarization strategy.

The two dimensional logical grid shows in Figure 12, the geographical area in graph split into two grids x, y coordinates and physical size is d ×d. The transmission range of vehicle node is denoted with r and grid size denoted by, d $= \frac{r}{2\sqrt{2}}$, the vehicle is d as a maximum value. The vehicle is located at grid and broadcast packets to eight grid neighbors vehicles.

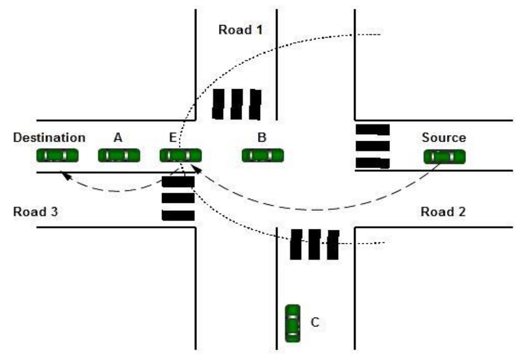

Figure 11. GpsrJ+ Prediction Process

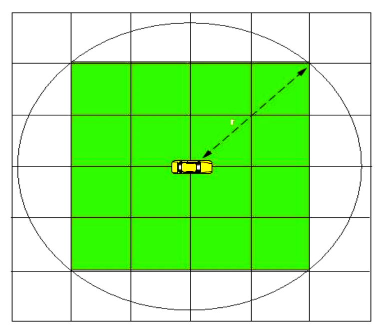

Figure 12. Two-dimensional logical grid

12) Grid-based Predictive Geographical Routing (GPGR)

The protocol GPGR was proposed in [37], based on grid predictive approach, where it makes road grids for the path movement and forecast the precise movement position along the road grids. The protocol considers the road topology information, which offers through static street map. Then starts the process of packet forwarding with the help of vehicle position, movement, velocity and road topology information between vehicles. This approach improves the routing in inter vehicular communication (IVC). Global positioning system, which is the most correlated geographical protocol, provides the information to the vehicle about their location and street. GPGR decreases the local maximum issues and link failure due to its decision based on mobility and road topology information. The advantage of GPGR is providing better packet delivery even though in low link cases especially compared with GPSR and GPCR in VANET.

13) Connectivity-aware Routing (CAR)

Connectivity-aware Routing (CAR) was presented in [38] for VANET based on adaptive beaconing mechanism. In this approach, the beaconing interval is distorted according to the number of registered nearby neighbors, and all nodes include information of moving direction and speed in Hello beacons. The protocol contains four things: path discovery, forwarding data packet along the path, maintenance with the help of guards and error recovery. The protocol predicts the position of destination vehicle and node reforms the route if node position is change.

When a node receives beacon message then it adds the information in neighbor table and approximates the neighbor and its own velocity vectors with expiration time. To decrease the loss of bandwidth and congestion, beacons might be piggybacked, and if the space between the nodes surpasses the threshold rate, accesses will run out from the neighbor table. The protocol uses a guard for route maintenance and guard stay alive as an entry in the periodic HELLO beacon of a node. The guards are divided into two types standing and travelling guard. The standing guard represents temporary state information such as the geographical area, rather than to a specific node. In travelling guard, the entry is in the form of ID, guarded position and radius, time-to-live (TTL) counter. The guard filter adds information and deliver the information to the destination. The guard overcomes routing errors due to a gap in the communication between anchor points or due to problems in guard themselves. The protocol also devises two-recovery approaches time out algorithm with active waiting cycle and walked around error recovery. The CAR protocol has a unique merit because guards create the virtual information.

14) Greedy Traffic-aware Routing (GyTAR)

The GyTAR routing protocol was proposed in [39] for inter-vehicle city environment. The protocol uses GPS and handles the relay data with real time information and utilizes the urban environment characteristics. GyTAR works with two modules: selection of junction and improve greedy forwarding methods between two junctions. The junction defines as, where many roads meet. In junction selection, the protocol finds routes and utilizes a carry and forward method for local maximum recovery. GyTAR uses the digital map for identify the neighbors junctions and their location. GyTAR selects the connection on the basis of traffic density and curve-metric distance to the target node. Figure 13, shows the selection process of next junction in street. The vehicle node A receives a packet and calculates the score of neighbors' junctions based on traffic density Tj and curve metric distance Dj to the destination. The junction j2 with the highest score selects as the next anchor by real time, traffic method with higher connectivity. After the selection of junction, the improve greedy approach uses to forward the packet between two junctions.

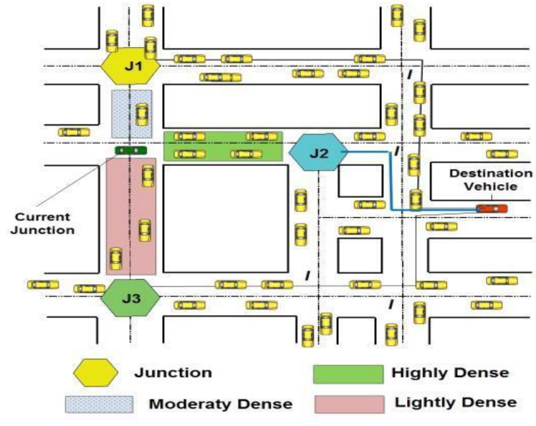

Figure 13. GyTAR Junctions Selection

15) Landmark Overlays for Urban Vehicular Routing Environments (LOUVRE)

The LOUVRE protocol was presented in [40], to build a landmark overlay network on the top of an urban topology with two metrics road length and density for route creation. The protocol ensures to avoid the obstacle for routing on the overlay links. The protocol classified into two composites: geo-reactive overlay routing and geo-proactive overlay routing. In the first category, the next super imposed vehicle node determines through distance between destination and neighbor nodes. The second category is based on a series of over laid node, which determines by GSR, A-STAR and LOUVRE protocol fit in to this composite. Protocol uses Dijkstra's algorithm for create the overlay link state routing table.

Figure 14, illustrates the function of LOUVRE protocol, where source S node routes the data to the destination D. Source sends the data through greedy forwarding and selects the solid node to the next node within each consecutive road until success. When S sends packets to D outside its grid, it simply routes towards nodes on Rd 6 on the boundary. These nodes maintain routing tables for cross-grid LOUVRE routing.

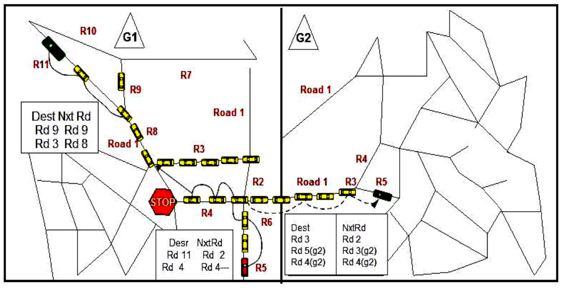

Figure 14. LOURVRE Function

16) Diagonal Intersection-based Routing (DIR)

The DIR protocol was presented [41] as an enhancement of CAR protocol. The protocol creates a sequence of diagonal intersection between sender node and target node. The protocol depends on the geographical information to advances the data packet towards the diagonal intersections (1,2,3) until the last diagonal joint. The auto-adjustability is one of the efficient feature of the protocol and attained by, where each-path dynamically selects route by consider the data packet delay. The selected sub-path with lowest delay automatically reroute. Because of this strategy, the data packet delay reduces. DIR protocol performance is better than CAR in terms of three metrics throughput, data packet delay, packet delivery ratio. It is best for real time applications like video streaming, video advertisement, and online games.

17) Receive on Most Stable Group-Path (ROMSGP)

The ROMSGP was introduces in [42], for metropolitan environment in order to enhance routing consistency. In this protocol, vehicles are divided into four groups according to their velocity headings. If two vehicles belong with the same group, so the protocol considers stable one and if the vehicles are not belonging to same group, it considers as unsteady. The Figure 15, shows the ROMSGP routing process, where vehicles are divided by vector base grouping technique and into four groups. Decision is based on most stable link by calculating the LET of each path. The protocol performance is greater in terms of high throughput, network overhead and high stability.

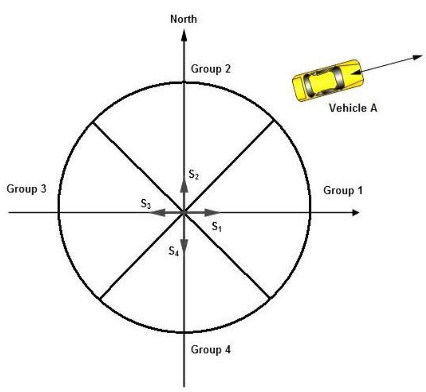

Figure 15. Velocity-Vector Based Grouping of Vehicles

18). Junction-based Adaptive Reactive Routing (JARR)

The JARR was proposed in [43], for VANET environment. In urban environment, various possible junctions and paths are available for routing. However, the shortest path routing does not feasible for metropolitan areas because vehicles must occupy every path for routing. The multi-hop routing protocol is efficient solution to select an optimal route and scalable for crowded network conditions. The JARR is a novel position based routing protocol based on density estimation. JARR comprises different components for routing such as location service, beaconing, and forwarding and recovery strategies. The protocol obtains vehicle velocity, position and direction information by beaconing messages and adjust the beaconing rate accordingly. The JARR protocol performance is better in dense environment in terms of packet deliver and network overhead.

19) Edge Node Based Greedy Routing (EBGR)

The EBGR was presented in [44], as a position-based greedy forwarding routing protocol for VANET. The protocol is designed for unicasting and broadcasting communication. In unicasting, the data sends from any vehicle node to any other vehicular node, in broadcasting the data is sending to one vehicle node to all other nodes. The basic idea behind this protocol is optimizing the packet behavior and delivery with high reliability in vehicular high mobility environment. The protocol selects the border node with limited radio range for selecting an optimal next hop and determines the direction of the destination.

The EBGR protocol uses three methods: neighbor node selection, node direction identification, and edge node selection method. In the first method, the source node collects the information from direct neighbor node, which is in radio range and second method is to identifying the direction of moving nodes, which are going toward the destination and in last method source selects the edge node as a next hop node within the transmission range to forward the packet. Through these methods, the protocol is able to minimize the number of hops and maximize the network throughput.

20) Border Node-based Most Forward within Radius (B-MFR)

The B-MFR was presented in [45], based on maximum projection. The protocol selects the border node within the sender transmission range and minimizes the number of vehicle nodes between source and destination. The protocol categorizes vehicle nodes into three classifications: interior, border, and outer nodes. The interior nodes belong to inside the circle range and the border nodes located near with the edge of range circle and the outer node are outside the range.

The source node broadcasts the beacon message to obtain the information of neighbors node. All nodes, which are located in the range of source nodes called one-hop neighbor, the source node find the list of a one-hop information then selects the next forwarding node. The protocol selects the border node for forwarding the packet because it is farthest from the source and nearest from the destination node. The packet sends to the border node with the best movement between source and destination, which is projected on the line drawn from the source to destination.

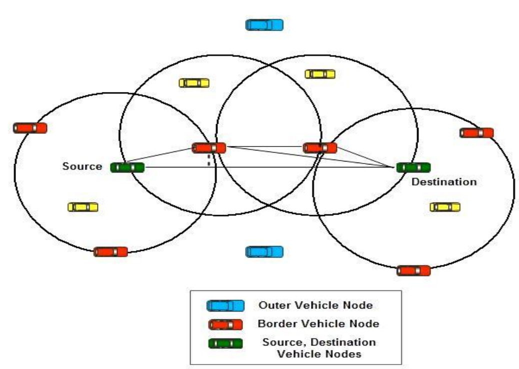

Figure 16. B-MFR Routing Process

In Figure 16, source node S has border node A and A positioned at maximum transmission range and the maximum progress distance SA where A is projection of A on SD. This is the reason A selects as a forwarding node and again A starts the same process for selects node B as a border node of A. In last, the node B directly delivers the message to destination node D. The protocol still has problems with inconsistent nodes, where two nodes are projected with similar point between source and destination with same distance, in this situation the protocol decision is difficult.

21) Adaptive Movement Aware Routing (AMAR)

The AMAR was presented in [46], based on greedy forwarding method for select the next hop from the source. The AMAR protocol solves the issues, which are in B-MFR to add information about vehicle movement. The protocol uses parameters of speed and direction to select the border node out of the two conflicting nodes. The algorithm computes the weighted score W_i for edge node i based on the speed, place and direction.

$$W_i = \alpha_{Pm} + \beta_{Dm} + \gamma_{Sm}$$

The β and γ are denoted as weights of metrics and $_{Pm}$ (position), $_{Dm}$ (direction) and $_{Sm}$ (speed) respectively, with $\alpha + \beta + \gamma = 1$.

The next hope candidate selection is based on the calculated score W_i. The highest weighted score node is selected as a border node for forwarding the data, through this calculation, protocol improves data delivery. However, protocol has one issue, if weighted score of two border nodes is equal, then again decision is complex for selecting the forwarding node.

22) Topology-assist Geo-Opportunistic (TO-GO) Routing

The TO-GO was proposed in [47], as an enhancement of GpsrJ+ and uses opportunistic forwarding method. The protocol maximizes the expected packets progression to the target. The protocol describes as an applicant set which is responsible for forwarding the set between the sender and the anchor node. The protocol uses enhanced beacon technique for prediction the target node. The target node is junction node or may be furthest node. The every node sets a timer and timer can be computed as follow:

$$T = C \times \frac{\text{Dist (receiving node, target node)}}{\text{Dist (sending node, target node)}}$$

The C denotes the maximum forwarding delay and differs with the processing time, transmission rate, and throughput. Between sending and receiving nodes, the T is relative value. The closer nodes use less time and farthest node take more time. The timer of closer nodes is accountable for shorter propagation delay, where every node begins the timer at around the same time. The TO-GO protocol is better compared with GpsrJ+ in terms of data packet delivery.

b) BEACONLESS PROTOCOLS

To make routing efficient, the geographical beaconless strategies have been proposed without using regular beaconing messages in network. These beaconless routing protocols use control messages instead of beaconing messages to find the neighbors nodes. In this section, we discuss some beaconless routing protocols.

The contention-based forwarding **(**CBF) protocol was presented in [48], and do not utilize beacon messages. Usually, the beacon messages are utilizing more bandwidth compared to beacon based routing. The CBF protocol broadcasts the data packet to all direct neighbors and identifies the optimal node for data forwarding. The source node selects the forwarder node based on dispersed timer-based contention process. In this process, the appropriate node onwards the packet and hold back other possible forwarders. When a node receives forwarded data then contrast their distance with the destination and with last hop's distance to the destination. The protocol saves network bandwidth and reduces the packet crash probability and incompetent routing. Protocol is better in highways environment and avoid local maximum issue but in an urban environment the protocol faces local maximum problem, due to destination may lie on diverse paths.

Some other beaconless routing protocols have been proposed for VANET to overcome the routing issues in network such as BRAVE [49], LIAITHON [50], and CAIR [51]. BRAVE is a beaconless routing protocol based on spatial awareness to allow intermediate nodes to change the initial plan based on the street map and local information. This protocol is not efficient in less dense areas and leads to high end-to-end delays and network overheads.

LIAITHON is a multipath receiver-based protocol which uses location information to discover the optimal route. It uses geographical advance, link quality and degree of closeness to forward the data toward the destination.

The CAIR is based on the high probability of connectivity. It is an intersection-based protocol with three operations: selection of intersection, prediction-based greedy forwarding, and recovery mode. For the first operation, a rectangle restricted area searching method is used to find the route in large-scale VANETs. The restricted area can be plotted by bounding the ellipse. The city environment is congested with different types of obstacles, so the protocol faces a delay issue in the network because of its rectangle strategy.

4.2.3 Routing protocols for delay-tolerant networks (DTNs)

Delay tolerant networks (DTNs) protocols have been proposed to overcome technical issues in mixed networks such as disconnectivity problems. The VANET usually faces these problems due to extreme high mobility of vehicles. In DTN protocols, the packet delivery increases by authorizing the nodes to store the packets when they lose connection with other nodes. In this section, the most well-known DTN routing protocols are discussed. The vehicle nodes get the packet for a certain distance and adopt carry-and-forward strategy. In this section, we discuss most well-known delay tolerant routing protocols.

1) Scalable Knowledge-based Vehicular Routing (SKVR)

The SKVR was presented in [52], based on two classes of knowledge at diverse hierarchical level. These levels are known as inter domain and intra domain. In inter-domain routing, the source and destination nodes fit in to diverse routes and in intra domain; they fit in to same routes. The inter-domain protocol forwards the message to the node, which is travelling in the destination domain. In intra domain, routing messages nature is to forward data packets in reverse directions and depend on contact list entries. The sending vehicle node delivers the packet to other vehicle if no vehicle in the destination domain exist in contact list. The protocol performance is greater in terms of data delivery and delivery delay.

2) Vehicle-assisted Data Delivery (VADD)

Another effort VADD was presented in [53], based on carry-and-forward approach for high mobility environment and uses vehicle conventional mobility. In this protocol, the vehicle takes decision at an intersection and selects the next onward path for packet forwarding. The packets are switching between intersection, straight way, and destination. The protocol has better performance in terms of data delivery ratio, data packet delay and traffic overhead.

3) Geographical Opportunistic (GeOpps)

The GeOpps was proposed in [54], as a geographical delay tolerant routing protocol based on GPS information. Through navigation system information, protocol selects vehicles, which might be travel closer to the final destination. The protocol calculates the straight distance from destination and checks the adjacent point (NP) from destination for packet delivery, and calculates the arrival time of packet towards the destination. The Figure 17, presents the protocol function, source A wants to send the packet to destination D and two nearest vehicle points are N1 and N2 to the destination. Node A pick N2 for forwarding and if another vehicle node is present with shortest approximate arrival time, the process is repeated.

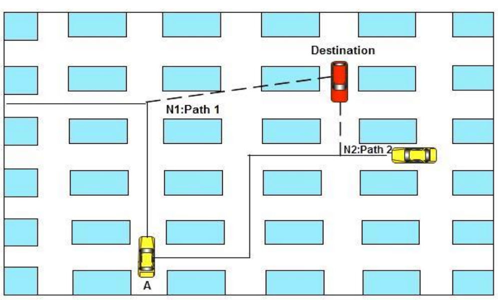

Figure 17. Function of

4.2.4 Hybrid position-based protocols

In this type of routing protocols, the data forwards between source and destination nodes by recovery and greedy modes in geographical routing. In greedy mode, the packets transport to the target node greedily and select the neighbor with good movement towards the destination. When the neighbor node is not closer to the destination due to obstacles in urban environment then the packet can reaches to local maximum. In this case, the recovery mode computes and extract the packets from local maximum and eventually returns to the greedy mode. After this process, the packets are ready to deliver across the obstacles towards the destination.

The connectivity between nodes in network assures when the network connect without any disturbance, but in case of VANET the network disconnects frequently due to high mobility and partitioned predominantly in sparse networks. However, the greedy and recovery modes are not feasible for VANET environment. In hybrid, position based routing protocols, the two strategies DTN and non-DTN merged to overcome this problem. In this section, we discuss some popular hybrid protocols.

1) GeoDTN+Nav

The GeoDTN+Nav was presented in [55], as a position based hybrid routing protocol and uses both DTN and non-DTN strategies. The protocol switches in between non-DTN and DTN modes, based on neighbor data delivery quality, neighbor direction, number of hops. The DTN mode delivers the packet even in disconnected or division with the help of vehicle mobility. The packet forwards first and using greedy mode then recovery mode when a packet hits a local maximum. In the case of recovery mode, protocol switches to the DTN mode and relies on vehicle mobility for deliver the data packet. The Figure 18, shows the transition diagram between these three modes.

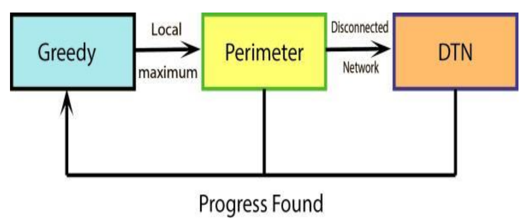

Figure 18. Three modes greedy, perimeter, and DTN

4.1 Cluster-based routing protocols

The cluster based routing protocols are more appropriate protocols for VANET based on suitable network cluster topology. In these types of protocols, every vehicle node has one cluster head, which is responsible for intra and inter domain management. The intra-cluster nodes interrelate with each other through direct link and inter-cluster interact through cluster head performance. The Figure 19, shows the clusters division in network.

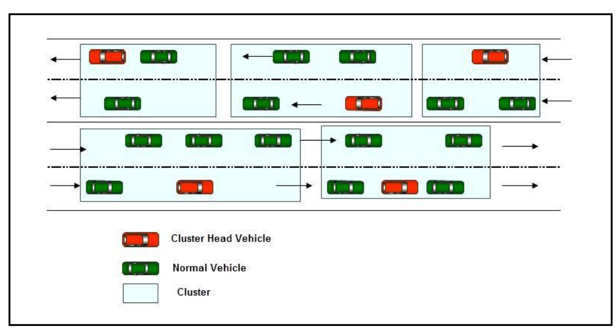

Figure 19. Multiple Clusters in Cluster-based Routing

In cluster based protocols, the vehicle nodes are close in network and make a cluster. However, some issues exist in these protocols such as configuration of clusters and selecting a cluster head. In this section, we discuss most popular cluster based routing protocols.

2) Cluster-based Routing (CBR)

The CBR was presented in [56], which separated the geographical area into square grids. For data delivery, the source node selects the efficient neighbor as a cluster head for data forwarding as a next hop based on geographical information. The protocol does not discover the route, because the route information is already store in routing table. The cluster head sends a LEAD message to its neighbors and organize location and grid. If the roadside unit exists in a grid, it will select as a cluster header. Whenever header exits in the grid, it sends a LEAVE message with grid position and store in an intermediate node until new cluster head selection. The information of new cluster head store in data routing table. The protocol is not using velocity and direction as a routing metrics, and these are important in VANET environment.

3) Cluster-based Directional Routing Protocol (CBDRP)

The CBDRP was proposed in [57], make many clusters when the vehicle nodes moving in the same direction such as highways. After the cluster division, the protocol selects one header in each cluster. The Figure 20, shows the cluster division into two clusters, where center position is fixed. The radio radius denotes with r, the length of each cluster id is d, and width of the highway is w, and d > w, and the d is almost equal to r/2. The standard radius in 802.11p is 1,000 m and cluster theoretical length is 500m. The d is much larger if header approaches the center position.

The source node with functionality of CBDRP sends the message to its cluster header and then send the message to another header, which is in the same cluster as a destination header for forwards the packet to destination. The selection of cluster header is same like in CBR protocol but getting the information of speed and direction of the vehicle. The protocol solves the link stability problem.

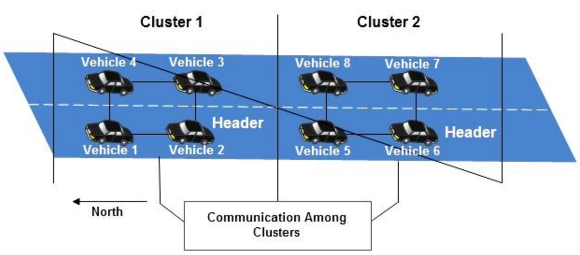

Figure 20. Dividing Clusters

4.2 Geocast-based routing protocols

These protocols are multicast routing protocols and advance a message to all the vehicles in a permanent geographical area. In this type of protocols, the node sends the data to all other node, which are in geographical area or zone of relevance (ZOR) [8]. The ZOR is geographical region and in this region the vehicles node receive the geocast messages.

Figure 21, shows the ZOR region and enables Geocast service. It describes a forwarding zone and direct the flooding packets to decrease message overhead and congestion in network. Usually congestion is caused by flooding packets in network. In destination zone, the unicast routing is used for data forwarding. One main issue in Geocast approach is network separation and presence of harsh neighbor's cause of delay in network.

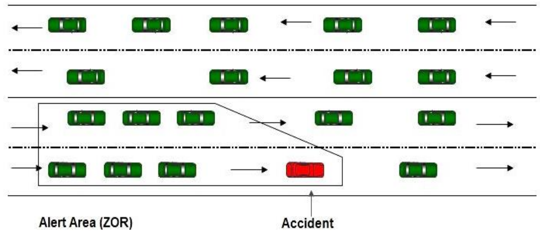

Figure 21. Geocast Routing In Vehicular Ad hoc Networks

1) Inter-Vehicle Geocast (IVG)

The IVG was illustrated in [58], based on distributed information about security in VANET like accident, floods. In this protocol, risk areas are establishing with the help of vehicle position and driving direction. The GPS is used for position and direction of vehicles. The vehicle receives and stores the messages for a certain period or defer time and then rebroadcast. The defer time ends and not receive any alarm message from behind; the protocol perceives no relay nodes. It allocates relay node itself and broadcast the alarm messages to alert the vehicles might be at the back of the vehicle. With the help of GPS the protocol, control the alarm messages distribution to applicable areas. These areas describe the members of the multicast group geographically. Through this process, the double advantages are there, it enables to avoid maintenance operations of the multicast tree such as neighbor computation and routing. However, these operations are very expensive in high mobility environment like transportation systems. The reliability and scalability of IVG protocol is better.

2) Robust Vehicular Routing

Robust Vehicular Routing was proposed in [59], as a geographical multicast routing protocol, which control the flooded packets in network and data packets are unicasted. The every vehicle has unique vehicle identification number (VIN) and GPS receiver for digital map. The protocol sends the message to all vehicles, which are in ZOR, and ZOR defines as a rectangle specify by its corner coordinates. The message defines by the three letters [A,M,Z] where A for application, M for messages and Z for all vehicles within an application-specified ZOR. Vehicle accepts the message, if it is within the ZOR of the time reception like in geocasting protocols. It defines zone of forwarding (ZOF) as a zone including the source and the ZOR. All the vehicles which are in ZOF and part of the routing process, where vehicles in ZOR deliver the message to their corresponding application layer A. The protocol uses a reactive route discovery process within the ZOR. Protocol creates many redundant messages in the network, the numerous message create congestion and packet delay problem in network.

4.3 Multicast-based routing protocols

The multicast transmission is a scheme where source transmits to multiple destinations based on geographical region. Traditionally these types of protocols are designed for wired networks and not working well in VANET environment. VANET multicast protocols adapt some characteristics from previous multicast protocols. These protocols consider high mobility, speed, frequent changing topological, link state information, constant deli updates, as accurate as achievable. VANET environment is suitable for multicast routing because of its nature of broadcasting to all nodes within the range. Many protocols have been developed for mobile Ad hoc networks and majority of them are valid for VANET. In these protocols, the sender and receiver construct tree or mesh as the routing structure. The multicast routing protocols are divided into two types tree-based and mesh-based. The most popular multicast protocols are multicast Ad hoc on-demand distance vector (MAODV), multicast with ant colony optimization based on MOADV (MAV-MAODV).

5. VANET Mobility Models

The authentic mobility models for designing routing protocols and testing protocols consider as a significant factor in VANET. Various studies suggested realistic mobility models such as street maps structure, vehicular movement, vehicle speed and density, obstacles models and more [60, 61]. These restraints are divided into two parts: Macroscopic and Microscopic; the macroscopic are refer to streets, roads, lights, and buildings and microscopic are refer to vehicle mobility and their behavior. The mobility models can also be considered as traffic motion generator and motion control by car driver habits, cars, and illustrate each vehicle movement. The traffic generator creates topological maps and set the lanes, roads, streets, obstacles, and car velocities and set the simulation time. Another method to detain a realistic model is to create patterns from mobility traces such as event-driven models, surveys models, software-oriented models, and synthetic models. Figure 22 shows the snapshot of mobility generator.

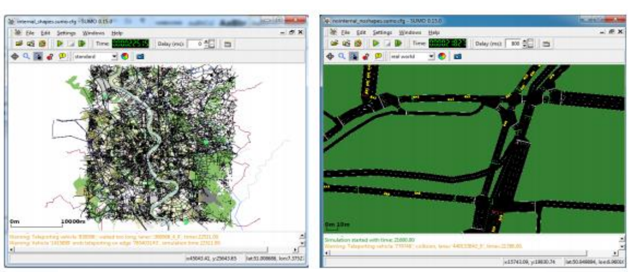

Figure 22. VANET Mobility Generator

6. Comparison and discussion of issues related to VANET routing protocols

During our survey, we also identified various predictive protocols like MURU, PDGR, and GyTAR. In these protocols, the existing position of vehicles stands on their last recognized position, and velocity predicted. Further, RAODV protocol predicts the stability or probable lifetime of a route. For routing decision, the predictive protocols take the characteristics of mobile vehicles and adopting the driver behavior for efficient predictions. The driver behavior is a significant factor for instant individual lane changing, breaking, and passing behavior. The designing of the new protocol that can predicts driver intensions and contribute to accurate predictions of an efficient route. The network segmentation is not suitable for VANET because of sparse environment. Most VANET routing protocols are new, and most of them are not, to make our paper more useful for researchers, Table 1 presents all previous VANET routing protocols and their characteristics.

The VANET technology has been faced various critical challenges because of high mobility of nodes and frequently topological changing environment; these issues disturb the packet delivery within the shortest time. Many researchers have been focused to proposed efficient routing protocols, which are suitable for high dense environment. The efficient routing protocols considered many factors like enhancing the system reliability and reducing the interference, considering scalability, delivering a packet within shortest possible time.

In this survey, we presented an inclusive investigation of popular VANET routing protocols. A number of protocols are working in vehicle-to-vehicle environment. Through this comparison, we identified many relevant issues in protocols such as traffic awareness, routing strategy, prediction, and network connectivity. The traffic awareness means the protocol capability to use traffic information and choose efficient route for sending the packets. Some protocols work on real time information like STAR and CAR, and some are based on probabilistic assumptions and static knowledge, including bus routes and lanes like A-STAR and VADD. Traffic awareness protocols are based on calculating traffic density, but none of them have elaborated how they get information on actual traffic. The STAR and CAR protocols are using real time measurement and solved this issue but not suitable in sparse traffic flow because the connection between vehicles are extremely poor and provide inaccurate calculation of road density. The two solution are available for overcoming this problem , the first is road side unit provides the regular updates but it is costly and second is developing a new traffic-density estimating protocol. The protocol is based on dynamic transmission range concept and taking into consideration the real-time traffic flow in sparse and dense conditions.

From beginning to end in a depth survey, we found two main strategies using in routing protocols: buffering and forwarding. In sparse networks, the node may maintains a packet in a local buffer until forwarding rather dropping the packet and in forwarding strategy the protocol takes first routing decision that when certain packets have to be forwarded. The VADD and SKVR using buffering strategy and improve performance in terms of packet delivery ratio and need to improve end-to-end delay in network. One solution to solve this issue is increasing the transmission range, and it helps to raise the probability of vehicle connection and reduces packet-buffering time.

Table 1. Comparison of VANET Routing Protocols

VANET Protocols	Environment	Forwarding strategy	Predictive	Buffering(carry and forward strategy)	Overlay or Non overlay	Positioning system required
DSDV,GSRP,FSR OLSR,WRP,TBRP F,ZRP,HARP	Urban	Multi-hop	×	×	×	×
TORA, AODV, DSR, AODV+PGB	Urban	Multi-hop	×	✓	×	×
PRAODV	Urban	Multi-hop	✓	✓	×	×
GPSR	Highway	Greedy	×	×	×	✓
GPSR+AGF	Urban	Greedy	×	×	×	✓
GSR	Urban	Greedy	×	×	✓	✓
SAR	Urban	Greedy	×	×	×	✓
A-STAR,STAR	Urban	Greedy	×	×	✓	✓
MURU	Urban	Greedy	✓	×	×	✓
GPCR	Urban	Greedy	×	×	✓	✓
GpsrJ+	Urban	Greedy	✓	×	✓	✓
GPGR	Urban	Greedy	✓	×	×	✓
PBR-DV	Urban	Greedy	×	×	×	✓
CAR	Urban	Greedy	×	×	✓	✓
GyTAR,JARR,LOUVRE	Urban	Greedy	✓	×	✓	✓
DIR,ROMSGP,AMAR,EBGR,B-MFR	Urban	Greedy	×	×	×	✓
TO-GO	Urban	Greedy	✓	×	×	✓
SKVR	Urban	Greedy	×	✓	×	×
VADD	Urban	Greedy	×	✓	×	×
GeOpps, GeoDTN+Nav,LORA-CBF	Urban	Greedy	×	✓	×	×
CBR,CBDRP,COIN,TIBCRPH	Urban	Multi-hop	×	✓	×	✓
IVG	Highway	Multi-hop	×	×	×	✓
CGR,AGR,ROVER,Mobicast	Urban	Multi-hop	×	×	×	✓
MAV-AODV	Urban	Multi-hop	×	×	×	✓
MAODV,ADMR,MOLSR,ODMRP,D-ODMRP	Urban	Multi-hop	×	×	×	×

CONCLUSION

Communication between vehicles has become more critical for car designers and manufacturers in future. The vehicular ad hoc technology offers communication services for vehicles but still need improvement and enhancement.

In this survey, we discussed the issues, and problems involved in designing efficient routing protocols for VANET. We discussed the routing metrics, their function, characteristics, and routing philosophies. The previous proposed routing protocols do not deal efficiently with high mobility and dynamic environment of VANET and lead to disconnectivity, data delay, quality of services issues in network. Generally, position based routing protocols and geo-casting are more efficient than the other routing protocols. The various routing issues still exist in vehicular ad hoc networks and need more attention of researchers for better services in vehicular field.

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