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Working of various routing protocols in Vehicular Ad-hoc Network: A Survey

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Abstract: Vehicular Ad-hoc Networks (VANETs) is an improved form of Mobile Ad-hoc Networks (MANETs), where the vehicles moving in a predefined route with relatively high speed. Due to high rate of topology changes in VANETs, frequent disruption in link and excessive overhead occurs. An intelligent transportation system (ITS) is being approached by using VANET therefore the need of efficient VANET routing protocol is crucial. In VANET routing protocols, an efficient route must be established between nodes before communication can take place and it should adapt dynamic topology changes caused by rapid movement of vehicles. In this paper, different routing protocols in VANET are described which may help in designing improved routing protocols..

Keywords: Vehicular ad-hoc network, Routing protocols

I. INTRODUCTION

Vehicular Ad-hoc Network (VANET) is a sub type of ad-hoc networks. It needs no infrastructure (physical) to form a net- work. Real-time information is exchanged by the rapid moving vehicles, which assist the driver to escape the situations like traffic jams, accident etc. When vehicles want to transmit or exchange packets with each other using wireless channels a VANET is formed, this implies that vehicles must have the computerized modules and wireless transceivers to act as a network node. Communication in VANET is categorized into three types: vehicle-to-infrastructure (V2I), vehicle-to-vehicle (V2V) and infrastructure-to-infrastructure (I2I).

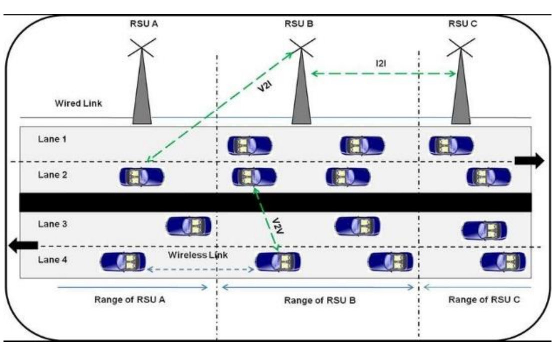

Figure 1. VANET Architecture [35]

VANET has tremendous prospective to enhance the safety of vehicles on road and traffic coordination. Applications of VANET can be distributed in two groups:

- Safety based Application: Application which can decrease the number of road accidents considerably
- User based Application: Applications which provide the road users with entertainment, advertisement and information throughout the journey. Information like traffic jamming, weather forecasting, nearest petrol pump or even details of cinema house can be accessed by the driver or passenger.

II. ROUTING PROTOCOLS

VANET routing protocol can be characterized according to the working, throughput and feasibility.

A. Topological based Ad-hoc Routing Protocol

In order to forward packets in the network, these type of protocols uses link information and generally these protocols are characterized as proactive, reactive and hybrid (combination of proactive and reactive) routing.

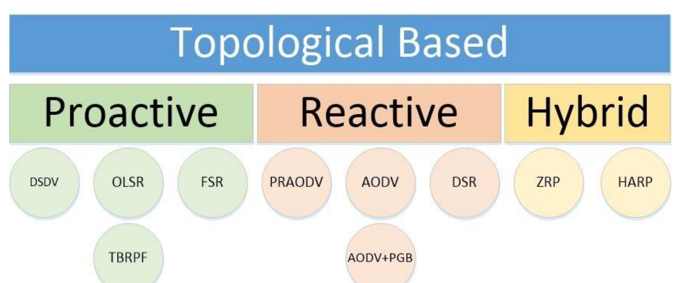

Figure 2. Topological Routing Protocols

1. Proactive Routing Protocols:

These type of protocols rely mainly on shortest path algorithm [47]. These protocol stores all associated nodes information in tables (routing table), then that routing information is exchange with other neighbors and the process of sending updates occurs until the network topology is changing. It does not initiate route discovery mechanism due to the updated routing tables which consumes too much bandwidth. This protocol works best when there is minimum mobility and the network is small.

a) Destination Sequenced Distance Vector (DSDV): DSDV [38] uses the Bellman-Ford algorithm [7] to minimize overhead of control messages, speed up convergence and make the routing path loop free. Each participating node in DSDV has a next-hop information table and they exchange routing information with the neighbors. There are two types of packets send by DSDV, 1) Full dump i.e. exchange of complete routing information and 2) Incremental dump i.e. only updates are exchanged.

c) Optimized Link State Routing (OLSR):

In OLSR [6], a pair of neighbor nodes is chosen by every node in the network called multi-point replay (MPR) which is responsible of re-transmitting the packets. Broadcast storm is minimized, as those neighbors can process and read the packet which are not present in MPR set, therefore routes are always available at any time when its needed.

d) *Topology Dissemination Based on Reverse Path Forwarding (TBRPF):*

In TBRPF [23], a source tree based assembling is done by all the nodes which is comprised of paths to accessible nodes based on partial information of topology. Slight change in Dijkstra algorithm and the topology table information is applied. By applying Hello beacon messages, the nodes are reorganized based on present and preceding condition of network. It means that the routing message can be sent more frequently to the neighbors due to the smaller size of the packet.

2) Reactive Protocols: These type of protocols updates the routing information whenever source wishes to initiate the communication. Route discovery is done using broadcasting and routing information about every neighbor node is constantly updated.

a) Ad-hoc On-Demand Distance Vector (AODV): In AODV [37], the neighbors are detected using the beacon messages when the source initiates the communication process. Source node initiates broadcasting route request (RREQ) packets to search a path of the destination node and every node broadcast the same RREQ packet until the destination is found. RREQ packets comprised on information i.e. IP addresses of both source and destination node, current and last known sequence number. Routing table gets updated with the address of the preceding node once the RREQ packet is received. A route reply (RREP) packet is unicasted to the source only when the destination node is found. A notification of link failure is sent when one of the intermediate nodes moves out from the path and then the process of route discovery will be re- initiated.

b) Dynamic Source Routing (DSR): In DSR [17], a complete list of nodes in sequence is carried in each packet header. Route discovery and route maintenance are the two basic phases in DSR. When a packet is intended for the destination whose path is unknown then a process of route discovery is invoked whereas route maintenance process is initiated when a broken link is detected between source and destination, it tries to use known alternative route for the destination at the start of route maintenance process or else a route discovery mechanism is initiated from scratch to search the new route.

c) Prediction-based AODV (PRAODV): In PRAODV [30], the source node receives the modified RREP packet from the intermediate or destination node. Information like velocity and packet location is included in each RREP packet. Prediction for lifetime of link is based on the velocity and location at each consecutive receiving nodes using the RREP packet destined to the source. Predicted link is compared at each node and swapped with the newer predicted value if the life span of link is greater. The velocity and location information is also updated with new values before forwarding it to the source, through this way the lowest cost of all links along with the route is approximated.

d) Preferred Group Broadcasting (AODV+PGB): In AODV+PGB [31], the overhead of AODV's route detection and its route stability is enhanced by minimizing the broadcast storm. Optimal conditions about the nodes can be distinguished by the receiver based on the signal received. Broadcasting is allowed from only one node but towards the destination it may not be ideal to generate significant progress. Therefore, it may take longer time to detect the path and it is also much possible that the mechanism of broadcasting may stuck in case of empty group.

3) Hybrid Protocols: Maintenance and route discovery is made more effective by dividing the nodes into zones in hybrid routing protocols which is basically a combination of reactive and proactive approach.

a) Hybrid Ad-hoc Routing Protocol (HARP): HARP [34] establishes non-overlapping zones by breaking down the network to improve delay factor by selecting steady route between source and destination. Within the network to restrict the route, implementation of route discovery is used among zones. Intra-zone and inter-zone are the two level in HARP which employs proactive and reactive protocols respectively based on the destination's location.

b) Zone Routing Protocol (ZRP): In ZRP [14], a group of nodes is referred as zones and the network is comprised on intersecting zones. A radius limits the area of zone where the size of radius depends upon the number of hops within the zone. Proactive routing approach is used in intra-zone interaction whereas reactive routing approach is used in inter- zone interactive. The data can be directly sent to destination by the source if both lies within same zone or else the inner- zone reactive routing protocol (IERP) will be responsible for detecting path.

B. Position Based Routing Protocols

Position based routing protocols are best suitable where rapid change in mobility exist in the network. These type of protocols tends to rely on the location information (acquired from GPS device) of the neighbor nodes with respect to the requesting node's location, therefore no route discovery is needed.

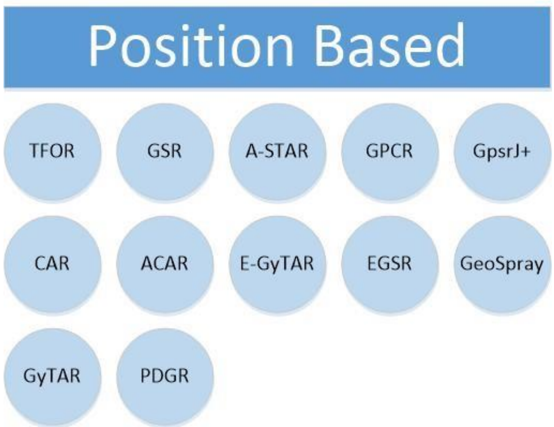

Figure 3. Position based Routing Protocols

1) Anchor-based Connectivity Aware Routing (ACAR): In ACAR [11], a hybrid protocol which use two techniques i.e. greedy forwarding and carry and forward to increase packet delivery ratio. ACAR is suitable in city environment where vehicles from both directions are utilized for quick communication. ACAR judges the connectivity between vehicles and then apply greedy forwarding technique first, if that technique fails then carry and forward technique is used especially in sparse network.

2) Anchor-based Street and Traffic Aware Routing (A- STAR): A-STAR [41] calculates anchor path using street maps same as GSR works but it also considers traffic density awareness while computing anchor path (using Dijkstra's Least Weight path algorithm) which makes this protocol viable for city environment. Each street is assigned a weight, lesser the bus-lines have greater the weight and vice versa. New anchor path is calculated when the known routes finds problem of local maximum. Use of anchor path sometimes causes a huge delay as the routing path chosen is not always optimal.

3) Connectivity-Aware Routing (CAR): CAR [32] finds the connected paths between source and destination not only the position of destination which is done by guards, even the destination vehicle moves a long distance from its last known position. Standing and travelling are the two types of guards used in CAR. Within the geographic area, a temporary information is hooked up in standing guards whereas the velocity vector, position and radius is contained in travelling guard. To maintain connectivity, after every specific time hello messages are sent to the nearby nodes. Populated path is always selected first whenever data transfer is required and frequency of the hello messages becomes high when the road has fewer vehicles.

4) Efficient Geographic Source Routing (EGSR): EGSR [13] protocol is based on ant colony optimization (ACO) that is basically an efficient form of GSR [25] which is useful for city environments because it considers traffic awareness. Using tiny control packets called ants are used for sampling traffic conditions and to compute shortest path, EGSR uses street maps but the length of the street is not directly proportional to the street segment's weight. Dynamic computation of the weights is done by considering the connectivity conditions of the streets.

5) Geographic Source Routing (GSR): In GSR [25], RLS is used for the discovery of path rather than beacon messages. To reach the destination the packet must be navigated through the sequence of junctions computed by each forwarding node. Due to dynamic changes in topology, Dijkstra algorithm is used by GSR to get the shortest path and lost packets are recovered using carry and forward techniques which means switching back to greedy approach.

6) Greedy Perimeter Coordinator Routing (GPCR): In GPCR [26], information like street maps and graph planarization are not used as it follows the fact that the streets and junction always build a characteristic planar graph. At every junction, the decision about packet forwarding is taken to avoid the packet forwarded crossway which means that a packet is always forwarded to the node which is available on the junction.

7) Greedy Traffic Aware Routing (GyTAR): In GyTAR [15] to transmit the messages, a navigation system which consist of GPS and digital maps is used in combination of traffic information. It is presumed that the current location of the destination node is known and a neighbor table is maintained by the vehicle using hello packets. The routing part consist of three strategies, a) Traffic density estimation using grid based information, b) Selection mechanism of intersection is done dynamically and c) Between two intersections improved greedy forwarding technique is used. By employing the above three strategies GyTAR achieves robustness to facilitate complicated urban environments.

8) GPSR Junction+ (GpsrJ+): In GpsrJ+ [21], reduction of overhead calculation is achieved by determining whether a node is found on a junction or not using electronic maps and also direction of vehicle is predicted by using the next- hop after the coordinator (the node located on the junction). The packet crosses the junction directly if the propagation direction does not change, rather than being re-forwarded by the coordinator which results in minimized number of hops and diminish the dependency on the coordinator.

9) Enhanced GyTAR (E-GyTAR): In E-GyTAR [3], GPS with combination of GLS is used to find the location of destination and for the selection of dynamic junction, speed and direction is also considered. To get the street information, a digital map is preloaded to the vehicle.

The score is as- signed at every junction to the vehicles, therefore the highest score will be selected which means that it is the nearest to the destination and travelling in the direction of destination vehicle. To send the data packets like GyTAR, E-GyTAR also uses the improved greedy forwarding technique where every vehicle maintains the information table i.e. velocity and direction at every junction about the other vehicles and that table gets updated using hello messages in specified interval and the local maximum issue is addressed with the carry and forward technique. The sender vehicle must query first to all its neighbors for appropriate path before sending the packets.

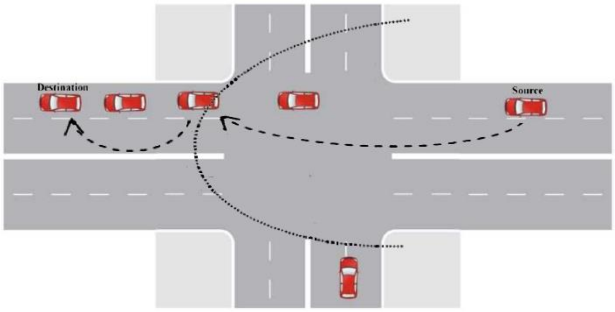

Figure 4. GpsrJ+'s Illustration

10) GeoSpray: In GeoSpray [42], a multi-hop path is built using the structure of Vehicular delay-tolerant network (VDTN) where hybrid method is adapted between single and multiple copy scheme. Number of bundled copies are retained and those copies are sent using multi copy scheme to find diversified alternative paths and then its switches back to store- carry and forward technique which not only enhances the packet delivery ratio but decrease the delivery delay as well. Between two map points GeoSpray calculates the distance, path and time interval then using the geographic information the bundles are forwarded to the destination.

11) Traffic Flow-Oriented Routing (TFOR): In TFOR [1], to achieve the strong routing paths it considers the traffic flow by selecting junctions (2-hop neighbors) which makes this protocol suitable for multi-lane (bi-directional) roads. GPS and GLS (Grid Location Service) both are used by TFOR to find the location of neighbor and destination nodes. The junctions are chosen dynamically, if the source node does not find any vehicular node in the direction of the destination vehicle keeping the consideration of flow of traffic density in both directions.

12) Predictive Directional Greedy Routing (PDGR): In PDGR [12], each vehicle broadcasts its own position and at the same time broadcast the position of its one-hop neighbors to get the packet dispatched towards destination. PDGR performs well in highway scenarios but the calculation overhead and propagation of two-hop neighbors are the drawbacks of PDGR.

C. Cluster Based Routing Protocols

A group of vehicles forms a cluster and communication between different clusters is the key responsibility of cluster head which exist in every cluster. Nodes can communication directly with other nodes within the same cluster whereas cluster head is used whenever communication is needed between different clusters. Due to high mobility, the configuration to form dynamic cluster is a major challenge.

1) Cluster Based Routing (CBR): In CBR [27], square shaped grids are created by dividing the geographical area where every node calculates the best possible cluster head nearby to them. It needs not to discover the routes, as those routes are already saved in the routing table due to which less overhead routing is achieved. The cluster head broadcasts a special message called LEAD to its neighbors which consist of the position of cluster head and the coordinates of its square grid. RSU will become the cluster head if lies in square grid. A leave message is broadcasted when the cluster head gets exit from the grid and that message carries the information of its grid that is temporarily used by the intermediate nodes till a new cluster head is chosen. The major drawback of this protocol is that it does not consider use of significant factors like velocity and direction.

Figure 5. Cluster based Routing Protocols

2) Cluster Based Directional Routing Protocol (CBDRP): In CBDRP [43] protocol, several clusters are formed based on vehicles traveling in same route. Communication can take place between each vehicle using radio signals with its neighbor clusters. The process of selection of cluster head is similar to CBR process, but CBDRP considers the factor of direction and speed of a vehicle. The results of simulation show that the CBDRP is useful in solving the link stability issue.

3) Clustering for Open IVC Network (COIN): Unlike the conventional clustering technique, in COIN [4] the cluster head selection process comprised on behavior of driver, mobility of node and distance between nodes instead of relative mobility which enhances a cluster's stability. To stay for a longer time in the radio range, the relative mobility between a member node and a cluster head should be kept low. This protocol minimizes the modification need in clusters association which increase the clusters a time to survive.

4) Location Routing Algorithm with Cluster Based Flooding (LORA-CBF): In LORA-CBF [40], within any cluster a node can become a gateway, a cluster head or a cluster member. Gateway is a node which is responsible for linking with other clusters. Managing the information of gateway node and its member nodes are the basic function of cluster head. Greedy strategy [10] is used for forwarding the packets. LREQ packets are the only messages that can be sent from gateway node and cluster head, upon receiving those messages the destination node is checked by the cluster head whether it is associates with its cluster or not. In case of success, the LREP packet is replied back to the sender using geographical position because each participating node is aware of the source location and its nearest neighbor based on the information collected from LREQ packet.

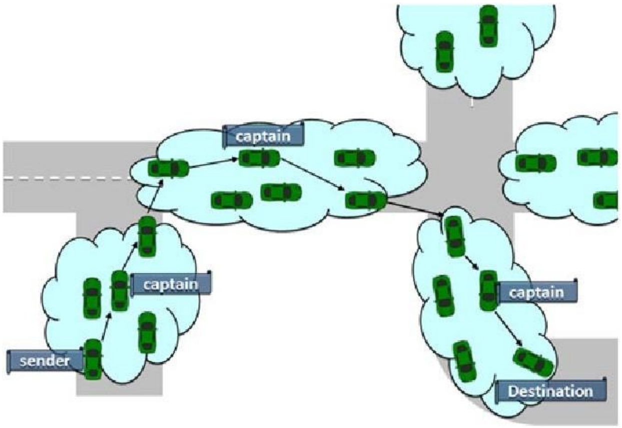

Figure 6. Moving Zone Based Architecture [24]

5) Moving Zone (MoZo): In MoZo [24], dynamic moving zones are formed using connected vehicles. Each zone elects a vehicle as a captain, which is responsible for managing messages and vehicles. Roads are converted into a graph, where roads act as edges and roads intersections as vertexes. Each road segment has starting point and ending point. Information of each vehicle like the distance from starting point and speed at specific time of any vehicle within the cluster is used by captain vehicle to estimate position of vehicle at specified time.

6) Traffic Infrastructure Based Cluster Routing Protocol with Handoff (TIBCRPH): In radio communication, it is not possible to stop overlapping (interference regions) between clusters where nodes of high mobility frequently required change of routes. The concept of handoff in TIBCRPH [45] protocol is introduced to mitigate the problem in cellular networks. Existing infrastructure is used to support the packet transmission where cluster head creates multiple clusters by dividing the network. Continuous transmission of packet and convergence of all roads is achieved by creating backbone network by each cluster head. When vehicle moves across the interference area, a dot product is produced using the direction and velocity vector of two neighboring cluster heads through which cluster head's ID is estimated.

D. Geocast Based Routing Protocols

In Geocast routing, a message is forwarded to all vehicles but within a specific geographical area which is usually called zone of relevance (ZOR) and that forwarding zone reduces the message overhead and network congestion.

1) Cached Geocast Routing (CGR): In CGR [29] protocol, local minimum problem is addressed by adding a cache to the routing layer to hold the packet only when a message cannot be delivered due to distance or unavailability of the receiving node. The cached message can be submitted when it finds new neighbor nodes. The nearest node to the destination is selected which lies within the range i.e. actually smaller than its transmission range. Decrease in network load and message delivery delay is done by considering persistent neighborhood changes.

Figure 7. Geocast based Routing Protocols

2) Inter Vehicle Geocast (IVG): In IVG [2] protocol, the information like position and driving direction of the vehicles (using GPS) is used to establish risked areas, for example accidents, flood etc. A message is stored for a specific time (called defer time), rather than instantly re-broadcasted when message received. If no similar message is received till the end of that defer time and also no relay node is detected, then it announces itself as a relay node and start broadcasting the messages to other vehicles. Defer time is inversely proportional to the distance that segregates them to make faster broadcasting and to lessen the time for wait from the desired furthest node. In highly dynamic environments these procedures are extremely costly.

3) Mobicast: In Mobicast [5], the time factor is also considered along with the space. The message is transmitted from source node to those nodes which is associated with ZOR at a specific time. For accuracy of ZOF estimation, it adapts zone of approaching (ZOA) to form flexible ZOF in order to propagate the message at a specific time to the ZOR.

4) Robust Vehicular Routing (RoVeR): To send the messages within specific ZOR, ROVER [18] unicast the control packets and those messages are accepted only when it lies within the ZOR. All vehicles use another zone that is created namely ZOF which is comprised of source and the ZOR. It uses reactive route discovery approach within ZOR that leads to creates redundant messages, which leads to congestion. To overcome this problem, the hop count in the packet, if that hop count reaches zero the packet will be dropped. Frequent packets are sent to those nodes which are closer to source and the sequence number is associated with each packet which helps in preventing redundancy of messages.

E. Multicast Based Routing Protocols

In multicast-based routing protocol, a single source node transmits the messages to multiple nodes with a geographical area which is conducted via Geocast routing.

1) Adaptive Demand-Driven Multicast Routing (ADMR): In ADMR [16], a periodic flooding of keep-alive packets is preserved by each tree. The routing state is organized and maintained for those active groups which comprised of one active sender and one receiver at least in the network. Receiver gets the packets transmitted from sender via path with shortest delay. The pattern of transmission from sender and mobility is dynamically adjusted by the receivers. This protocol also traces the mobility for the purpose of maintaining multicast

routing state efficiently. It traces the source inactivity and link breakage in the tree. Local repair process is started when it finds link breaks and if that local repair fails, a global repair is initiated.

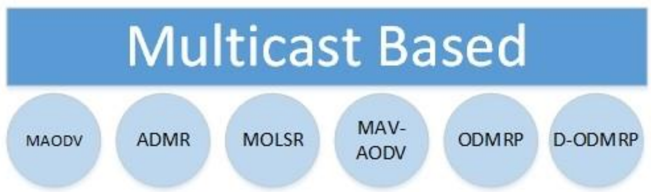

Figure 8. Multicast based Routing Protocols

2) Destination-Driven On Demand Multicast Routing Protocol (D-ODMRP): In D-ODMRP [46], to make efficient multicast forwarding source to receiver path is predetermined towards the direction where another multicast destination passes through. This protocol opts the path with least cost if it finds multiple path which tends to shorten the forwarding group. Route request is forwarded based on the metric of distance from where the last member visited of multicast group, each intermediary node is assigned a deferring time which increases if the distance is increased. Deferring time depicts the least cost of route request by classifying nodes that are traveling faster.

3) Multicast Ad-hoc On-Demand Distance Vector (MAODV): In MAODV [39] when joining to a multicast group is needed by the sender only then a RREQ message is broadcasted to the network, every other node then rebroadcast that message until it reaches the desired member of the group. The address of a node is stored in their routing table in order to identify the reverse route to the source where the RREQ was initiated and RREP packet is to be route back in a unicast manner to the source. Multiple RREP packet may be received by the originated node, the originator selects the shortest path (based on hop counts) and also send multicast activation message (MACT) along with that. The node will become the member of multicast group once the MACT is acknowledged and all other nodes in the selected path will become the forwarding nodes. The first member of any group i.e. group leader monitors the link status by simply sending Group Hello beacons in the group. Those nodes which are disconnected from a group can form new multicast tree and even they can select a new leader as well.

4) Multicast with Ant Colony Optimization for VANETs (MAVAODV): MAVAODV [44] is based on MAODV [39] protocol and it also adapts the principle of Ant Colony Optimization meta-heuristic [8] when the route is evaluated depending upon the route stability and volume of pheromone deposition. The stability is determined by sending beacons to let vehicles know the existing of other vehicles in that group. It does estimation of link lifetime through calculation, when any node receives a beacon message. This protocol defines two messages i.e. Ant-RREQ for route request and Ant-RREP for reply in multicast tree where first defined message is broadcasted for the destination containing lower hop count information and link lifetime at each packet. Reply is made only when a valid route exists and the correspondent sequence number is higher that the stored one. Routing table gets the information of next hop node where Ant-RREQ packet was received and an Ant-RREP packet is generated. An Ant- RREP packet which contains lifetime and hop count calculates the pheromone amount on the route traveled by Ant-RREQ packets.

5) Multicast Optimized Link State Routing (MOLSR): In MOLSR [20], source and multicast group pair is maintained in a distributed way, without any centralized entity and also from source to members of multicast group, it offers shortest path. The tree gets updated when a change or deletion occurred in topology. A source-claim message is sent which consist of its identity and list of members of that group when packets are needed to be transmitted to any multicast group. Building of branches in a tree is done by using a mode called backward mode which basically uses hop by hop. When source claim message is received by a group member and if that is not a member of that group, it simply registers itself and shortest path is calculated using subsequent hop information and then a message called confirm-parent is transmitted to it. The messages of source-claim and confirm-parent are used to get the tree frequently updated.

6) On-Demand Multicast Routing Protocol (ODMRP): A message of query called join is sent periodically over the network whenever a sender has data to send or wants to join the multicast group in ODMRP [22], by doing so the routing information and group membership gets updated. If a node receives a join query message and that node is not having the membership of any multicast group, then it checks for the duplication otherwise the information of upstream node's ID is stored and then the message is broadcasted. It connects the source to every member of multicast group just like a mesh. If any node stops sending join queries it means that node has quit the multicast group after which its route is deleted.

F. Broadcast Based Routing Protocols

In broadcast based routing protocols the messages are simply broadcasted to every other node which guarantees the arrival of message to all destination with very high overhead cost. Basically these type of protocols are suitable for small networks because it tends to consume huge bandwidth due to message collisions and duplications which decreases the overall performance.

1) BROADCOMM: In BROADCOMM [9], moving virtual cells are created by dividing the highway roads with equivalent length which is best suited for transmission. On highway, every node is categorized into two levels; each node within a cell is inclusive in first level whereas in second level, cell reflectors are represented which are basically those nodes which are geographically closer to the cell's center. The cell behaves as a cluster head for a specific time interval and takes care of emergency messages that are sent its members.

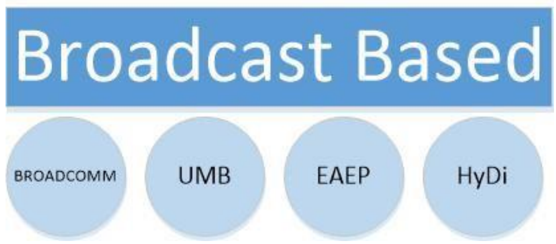

Figure 9. Broadcast based Routing Protocols

2) Edge Aware Epidemic Protocol (EAEP): In EAEP [33], the load of control packet is minimized by removing the swapping of beacon messages for transmitting packets between clusters of vehicles and it also release the load of cluster management. Front and back nodes transmission types are applied for a defined time whenever a new broadcast message is received and computation for the possibility of making a decision whether the message needed to be resend or not.

3) Hybrid data Dissemination (HyDi): HyDi [28] is aimed to perform well in complex scenario where traffic flows heavily in both directions. In this protocol, the broadcast storm problem is dealt by introducing sender-based and receiver- based methods. Node selects (derived by logic) the subsequent node where a message is to be received in sender-based method whereas in a receiver-based method, one of the node (derived from observed facts) that received the message is held accountable for the message being handled. It implements carry and forward technique and keep the message only when its find no other vehicle where message can be delivered until new connection is found.

4) Urban Multi-hop Broadcast (UMB): In UMB [19], the urban areas issues of multi-hop broadcasting like hidden node, reliability and broadcast storm are taken care of. In this protocol, the duty of forwarding and acknowledging is assigned to one vehicle by simply splitting the road section into different portions within the transmission zone and without a prior information that vehicle is selected from the portion that is found heavily populated amongst all portions. A directional broadcast is initiated by repeater when it finds an intersection in message dissemination path in order to reach other vehicle.

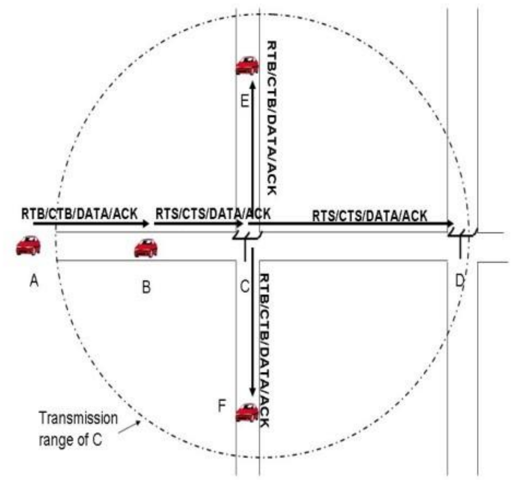

Figure 10. UMB Protocol [19]

III. CONCLUSION

ITS rely heavily on VANETs and the routing mechanism is an integral part of this technology. This survey paper contains the working of various protocols. However, it can be easily said that there is no single protocol which performs best in every scenario. Although Position based routing protocols seems to be more effective, as it employs location data which offers a further advantage for achieving superior performance. Challenging characteristics of VANETs must be dealt with effectively. Nevertheless, in VANETs it is still an open issue which is needed to be addressed which opens the door of research for improvement in routing protocols.

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