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Routing Protocols in VANET: A survey

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Abstract— Abstract: Vehicular ad hoc networks (VANETs) are classified as an application of mobile ad hoc network (MANET). VANET applications make travel both safer and fun. Vehicles can be turned into a network by incorporating the wireless communication and data sharing capabilities. So VANET provides promising approach for intelligent transport system (ITS). The design and survey of routing protocols in VANETs is important and necessary issue for the support of smart ITS. This paper discusses the classification of routing protocols based on the transmission strategies i.e. unicast, multicast and broadcast protocols.

Keywords— VANET, ITS, Unicast, Multicast, Broadcast

I. INTRODUCTION

With the increase of number of vehicles on roads in the recent years, driving has become more challenging and dangerous. Roads are saturated, safety distance and reasonable speeds rules are hardly obeyed, and drivers often lack the required attention [1]. Vehicular Ad hoc networks (VANETs) are a special type of mobile ad hoc networks (MANETs), where vehicles are simulated as mobile nodes. VANET contains two entities: access points and vehicles. Access points are fixed and connected to the internet and can participate as a distribution point for vehicles [2]. To increase the safety of drivers and provide the safe and comfortable driving environment, messages for different purposes need to be sent to vehicles through the inter-vehicle communications (V2V) and between vehicles and infrastructure access point (V2I) through wireless access called Wireless Access for Vehicular Environment (WAVE) [3].

Therefore, messages need to be routed to vehicles and different routing protocols are required for this purpose. The main goal of routing protocol is to provide optimal paths between network nodes via minimum overhead [2]. Although countless numbers of routing protocols have been developed in MANETs, many do not apply well to VANETs as VANETs represents a particularly challenging class of MANETs. They are distributed, self-organizing communication networks formed by moving vehicles, and are thus characterized by very high node mobility and limited degrees of freedom in mobility patterns [1]. VANET also has road pattern restrictions, and no restrictions of network size, all these characteristics made VANETs environment a challenging for developing efficient routing protocols [2].

Many routing protocols have been developed for VANETs environment, which are classified in different ways and aspects; such as: protocols characteristics, techniques used, routing information, quality of services, network structures, routing algorithms, and so on. Some research papers classified VANETs routing protocols into five classes: topology-based, position-based, geocast-based, cluster-based and broadcast based routing protocols [2] [4] [5] [6]. As well, other papers classified VANETs routing protocols according to the network structures, into three classes: hierarchical routing, flat routing, and position-base routing. Moreover, they can be categorized into three classes according to routing strategies: proactive, reactive and hybrid [8]. On the other hand other papers classified them into two categories: geographic-based and topology-based, according to the routing information used in packet forwarding [4] [7].

There is another type of classification of routing protocols based on transmission strategies i.e. Unicast, Multicast and Broadcast. Unicast routing provides information delivery between two nodes via multiple wireless hops. Multicast is defined by delivering multicast packets from a single source vehicle to all multicast members by multi-hop communication. It can be either Geocast routing which is a location based multicast routing, it delivers packets to vehicles located in a specific geographic region or it can be Cluster Based routing which divides the network into cluster where vehicles having similar properties like speed, direction etc. form a group. Broadcast protocol sends a broadcast message to all the other vehicles in the network [3]. Following section discusses the protocols.

II. UNICAST ROUTING PROTOCOLS

Unicast routing protocols transmits the data from a single source to a single destination through wireless multi hop scheme or the carry and forward scheme. In wireless multi hop technique the intermediate vehicles in a routing path relays data as soon as possible from source to destination. The carry and forward technique requires the source vehicle to hold the data for some time and then forward it. These two categories are classified as min delay and delay bounded routing protocols [2].

Various unicast routing protocols are discussed as follows:

1) Anchor-*based Street and Traffic Aware Routing Protocol (A-STAR):* A position-based routing scheme called A-STAR considers the challenges faced in a city environment. A-STAR adopts the anchor-based routing approach with

street awareness. “Street awareness" uses the street map information in computing the sequence of junctions or anchors through which a packet must pass to reach its destination. It uses traffic awareness to compute the anchor paths [9].

2) *Mobility-Centric Data Dissemination Algorithm (MDDV):* It is a mobility-centric designed to operate efficiently and reliably despite the highly mobile, partitioned nature of the networks. MDDV combines the idea of opportunistic, trajectory based forwarding and geographical forwarding. As there is no end-to-end connectivity therefore intermediate vehicles buffers and forwards message. MDDV answers the questions about who can transmit, when to transmit, and when to store/drop messages. Vehicles perform local operations based on their own knowledge while their collective behavior achieves a global objective. Message delivery reliability is improved by allowing multiple vehicles to actively propagate the message [8].

3) *Vehicle-Assisted Data Delivery Routing Protocol (VADD):* Data delivery routing protocol called as VADD adopted the idea of carry-and-forward for data delivery from a moving vehicle to a static destination. The selection of a forwarding path with the smallest packet delivery delay is the most important issue of the protocol. VADD protocol transmits packets through wireless channels as much as possible so that data transmission delay is low, and if the packet with higher speed is chosen firstly. The assumption made by the VADD protocol is that the vehicles are equipped with pre-loaded digital maps, which provide street-level map and traffic statistics such as traffic density and vehicle speed on roads at different times of the day. According to the information provided by digital maps, VADD protocol proposed a delay model to estimate the data delivery delay in different roads [10].

4) *Connectivity-Aware Routing Protocol (CAR):* Connectivity-Aware Routing (CAR) protocol overcomes the problem of frequent network disconnections in vehicular ad hoc networks (VANET). It addresses the problem by selecting an optimal route with the least probability of network disconnection using Dijkstra algorithm and avoids carry-and-forward delay. CAR protocol sends the searching packets to find the destination. Each forwarding vehicle records its ID, hop count, and average number of neighbours in searching packets. Once it reaches the destination, the destination chooses a routing path with the minimum delivery delay time and replies it to the source. While destination sends the reply packet to the source, the junctions passed are set as the anchor point. The data packets are forwarded in a greedy method toward the destination through the set of anchor points on the path setup [11].

5) *Diagonal-Intersection-Based Routing Protocol (DIR):* DIR is an improvement of CAR protocol. The difference of CAR and DIR protocols is that DIR protocol constructs a series of diagonal intersections between the source and destination vehicles. The DIR protocol is a geographic routing protocol in which source vehicle geographically forwards the data packet toward the first, the second, the third diagonal intersection, and so on, until the last diagonal intersection (destination) is reached. There exist two or more disjoint sub-paths between a pair of neighboring diagonal intersections. Auto-adjustability is the main property of the protocol i.e. it selects one sub path low data packet delay, between two neighboring diagonal intersections. Auto-adjustability is the noble property of the protocol. To reduce the data packet delay, the route is automatically re-routed by the selected sub-path with lowest delay [12].

6) *Dynamic source routing Protocol (DSR):* This protocol consists of two operations “Route Discovery” and “Route Maintenance” that makes it self-configuring and self-organizing. Another important property of DSR routing protocol is network type flexibility. Disadvantages of DSR The route maintenance mechanism does not locally repair a broken link The connection setup delay is higher than in table-driven protocols This routing overhead is directly proportional to the path length [13].

7) *Ad Hoc On-Demand Distance Vector Protocol (AODV):* AODV is a source initiated routing protocol and uses HELLO messages to identify its neighbours. In this protocol nodes keep a routing table (one entry per destination) for the known destinations. If a node needs to communicate with other nodes that are not included in its table, it initiates a route discovery process for a given destination. Such nodes broadcasts a route request (RREQ) to its neighbours which forwards it to the destination. The destination then unicasts a route reply (RREP) packet to the sender. Every node maintains broadcast-id which increments for new RREQ. When a RREQ arrives at a node, it checks the broadcast id if it is less than or equal to previous message then it will discard the packet [14] [15].

8) *Source-Tree Adaptive Routing Protocol (STAR):* STAR is a table-driven routing protocol. Each node builds a shortest path tree by discovering and maintaining topology information of the network to store preferred paths to destinations. The Principal mechanism in detection of neighbours and exchange of topology information (update message) among nodes is through: a) Hello Messages: Each node sends Hello messages periodically to inform its neighbours about its existence. On receiving it an unknown node discovers a new neighbour, b) Neighbor Protocol: It notifies STAR of the existence of new neighbours or the loss of connectivity to an existing neighbor. With the support of a neighbor protocol, no hello messages are needed [16].

9) Greedy Perimeter Stateless Routing protocol (GPSR): Greedy Perimeter Stateless Routing selects a node closest to the destination by using beacon. It uses greedy forwarding algorithm, on its failure it uses perimeter forwarding for

selecting a node through which a packet will travel. Under GPSR, nodes use a geolocalization system like GPS. The source node marks the packets with the destinations location obtained by a location service. A greedy choice is made by the source node in choosing the packets next hop allowing successively closer geographic hops, until the destination is reached. The only requirement of the protocol is for each node to know the location of its neighbours [17].

III. MULTICAST ROUTING PROTOCOLS

The multicast approach based protocols send the information to more than one node or to specific group members at a time by multi hop communication.
Multicast routing in VANETs can be classified into two categories: Geocast and Cluster-based routing.
The following section illustrates each class in more detail.

A. Geocast Routing Protocols

Geocast routing, is a location-based multicast routing. The objective of a Geocast routing is to deliver the packet from a source vehicle to all other vehicles located within a specified geographical region known as Zone of Relevance (ZOR). The membership of the node changes when the node moves out of the defined geographical area, and the packets are dropped in this case.

1) *Distributed Robust Geocast Protocol (DRG):* The Distributed Robust Geocast (DRG) delivers packets to vehicles located in a specific static geographic region. A vehicle should receive packets if it is located this specific geographic region called ZOR. Otherwise this vehicle drops packets. The vehicles are assumed to have a GPS receiver and access to a digital map. When a vehicle receives a message, it accepts the message if, at the time of the reception, it is within the ZOR. Zone of Forwarding (ZOF) is a zone including the source and the ZOR. All vehicles in the ZOF are part of the routing process, although only vehicles in the ZOR deliver the message to their corresponding application layer [18].

2) *Mobicast Routing Protocol:* Mobicast Routing Protocol includes ZOR and ZOF areas but the way of creating ZOR and ZOF is different from DRG. The ZOR is a function of time, in both shape and location, and the ZOF is created based on Zone of Approaching (ZOA). All vehicles belonging to the ZOR at a time t should stay connected to preserve the real time communication of data. The communication of ZOR fails if any ZOR vehicle unexpectedly speeds up or slows down. The ZOF should be determined accurately and efficiently. Under-estimation of ZOF leads to the temporary network fragmentation problem, and the over-estimation of ZOF results in the rebroadcasting problem [2] [19].

3) *Robust Vehicular Routing Protocol (ROVER):* ROVER is a geographical multicast protocol; which permits each vehicle to deliver a packet to all vehicles inside a specific ZOR. The technique used in ROVER is similar to AODV which consists in broadcasting only control packets, while data packets are unicasted. The ZOR is a rectangle area specified by its corner coordinates and ZOF includes the sender and the ZOR. This protocol creates lot of redundant messages in the network which leads to congestion and high delay in data transfer. ROVER defines a message as a triplet [Application, Message, ZOR] [2] [6] [20].

4) *Direction-based GeoCast Routing Protocol (DG-CastoR):* DG-CastoR (Direction-based GeoCast Routing), is a geocast routing protocol for Vehicular Ad hoc NETworks based on link availability estimation. It creates a virtual community of nodes able to communicate during a certain period of time. The Geocast routing area is created based on the prediction of future locations to estimate the link availability between mobile nodes. The main advantage of DG-CastoR protocol is the reduction of the network congestion by avoiding the unnecessary packets transmission on the whole network [8].

5) *Dynamic Time-Stable Geocast Routing Protocol (DTSG):* DTSG protocol works with sparse density networks. The protocol dynamically adjusts itself depending on network density and the vehicles speed for improved performance. The main goal is to inform vehicles belonging to a specific region on the highway for a certain period of time about an event (accident). The protocol works in two phases: pre-stable which helps the message to be disseminated within the region and stable period in which intermediate node uses store and forward method for a predefined time within the region. It also tries to balance between packet delivery ratio and network cost [6] [20].

B. Cluster Based Routing Protocols

Cluster based protocols divides the network to clusters, where the nodes having the same properties like same direction or same velocity, or so on form a cluster or a group. Each cluster has a cluster head, which is responsible for intra and inter-cluster management functions. Nodes inside the cluster communicate with each other using direct links. It provides good scalability for large networks; however it may increase network overhead and delays in highly dynamic network.

1) *Clustering for open IVC network Protocol (COIN):* COIN improves network scalability. It selects clusters according to three parameters: mobility of nodes, nodes positions and behaviour of nodes. Each cluster is provided specific time which is a time to live; in order to decrease control overhead [21].

2) *Cluster-Based Directional Routing Protocol (CBDRP):* In CBDRP the network is divided into clusters and vehicles which are moving in same direction form a cluster. The source node sends the message to its cluster head and then it forwards the message to head which is in the same cluster with the destination. At last the destination header sends the message to the destination. The selection and maintenance of cluster header is similar to CBR but the velocity and direction of vehicles are taken into consideration [20].

3) *Hierarchical Cluster routing Protocol (HCB):* Hierarchical Cluster routing protocol is designed for high mobility ad-hoc networks. It is two-layer communication architecture. In layer-1 nodes have single radio interface and communicate with each other via multi-hop path. Some nodes called super nodes have another interface with long radio communication range which exist both on layer-1and 2. Such nodes communicate with each other with the help of base station in layer-2. At the time of cluster formation, each node attaches itself to the nearest cluster header and super nodes become cluster headers in layer-1. In HCB, routing within a cluster is performed independently. Inter-cluster routing is performed by exchanging membership information periodically between cluster heads [20].

4) *Cluster Based Location Routing Protocol (CBLR):* It is a reactive and cluster based routing protocol. In formation of cluster every node broadcasts a hello message and waits for a predefined time. On receiving a reply it becomes the cluster member; otherwise, it becomes a cluster header. The information about neighbouring clusters is maintained in the Cluster Neighbor Table. When a source wants to send data to a destination, it first checks for destination if it's a cluster member. If it is then, it sends the packet to neighbor closest to the destination. Otherwise, the source stores the data packet, starts a timer and broadcasts Location Request (LREQ) packets. After receiving a request, each cluster-head checks whether the destination is a cluster member or not. If it is a cluster member, then cluster header sends a Location Reply (LREP) packet to the sender. Otherwise it retransmits to adjacent cluster-headers [20].

IV. **BROADSACT ROUTING PROTOCOLS**

Broadcast is an effective approach for safety-related information exchange such as emergency accident, traffic information services, announcements and advertisement by sending information to all nodes in the network to achieve cooperative driving in VANET [8].

Various broadcast protocols are discussed as follows:

1) *Urban Multihop Broadcast Protocol (UMB):* UMB (Urban Multi-Hop Broadcast Protocol for Inter- Vehicle Communication Systems) is operates without exchanging location information among neighboring nodes. In this the sender nodes tries to select the farthest node in the broadcast direction to forward and acknowledge the packet without any prior topology information. The protocol has a mechanism for minimizing hidden nodes problem, avoiding collisions and overcoming interferences at the time of message distribution. At higher packet loads and vehicle traffic densities the protocol performs the best [8], [21].

2) *Edge-Aware Epidemic Protocol (EAEP):* It is a reliable and highly dynamic VANET protocol. It eliminates the exchange of additional hello packets for message transfer between different vehicle clusters thereby reducing the control packet. Each vehicle piggybacks its own geographical position to broadcast messages to eliminate beacon messages. Upon receiving a new rebroadcast message, EAEP uses number of transmission from front nodes and back nodes in a given period of time to calculate the probability for making decision regarding rebroadcasting the message. EAEP overcomes the simple flooding problem but it incurs high delay of data dissemination [20].

3) *Distributed Vehicular Broadcast Protocol (DVCAST):* It uses local topology information by using the periodic hello messages for broadcasting the information. This protocol divides the vehicles into three types depending on the local connectivity: well connected, sparsely connected, totally disconnected neighbourhood. In well connected neighbourhood it uses persistence scheme. In sparsely connected neighbourhood on receiving the broadcast message, vehicles can rebroadcast with same moving direction vehicles. In totally disconnected neighbourhood vehicles store the broadcast message until another vehicle enters into transmission range, otherwise packet is discarded. This protocol causes delay and high control overhead in end to end data transfer [20].

4) *Secure Ring Broadcasting Protocol (SRB*): This protocol minimizes the number of retransmission messages and achieves more stable routes. It classifies nodes into three groups based on their receiving power: Inner Nodes (close to sending node), Outer Nodes (far away from sending node), Secure Ring Nodes (preferable distance from sending node). It restricts rebroadcasting to only secure ring nodes to minimize number of retransmissions [20].

5) *Preferred Group Broadcast Protocol (PGB):* Each node in PGB senses the level of signal strength from neighbor broadcasting. The signal strength is used for waiting timeout calculation. Nodes in the edge of circulated broadcast will set shorter waiting timeout. Only the nodes with the shortest timeout rebroadcast the messages. But there exists a problem on low density area. PGB is not a reliable broadcasting protocol but it is a solution to prevent broadcast storm problem from route request broadcasting [21].

6) *Broadcomm Protocol:* It is based on Geographical Routing and has a hierarchical structure. The nodes are organized in two level of hierarchy: in the first level nodes communicate with each other within the same cell and with the

nodes of neighboring cell and the second level are cell reflectors which are few nodes located close to the geographical center of cell and can communicate within the cell members or members of neighboring cells in the communication range of the cell reflector. Cell reflector behaves as cluster head for certain time period and handles the incoming emergency messages [8], [21].

7) *Distribution-Adaptive Distance With Channel Quality protocol (DADCQ):* DADCQ is a multi hop broadcast protocol for large networks with high node distribution. The selection of the forwarding nods for rebroadcasting the packets is done according to the positional information. While rebroadcasting decision, when a node receives a packet, it first checks its distance from the destination; if it was very close then no rebroadcast takes place because its rebroadcast will not cover a further area. However, if this distance is large, then the node has to rebroadcast the packet [2].

8) *Density-Aware Reliable Broadcasting Protocol (DECA):* DECA is a reliable broadcast protocol which utilizes store and forward transmission scheme. When a node broadcasts a packet, it initially chooses a next hop selected according to the amount of node information (largest density information) to rebroadcast the packet. Then that node adds the next hop ID to the packet and broadcast the packet. Other nodes that aren't next hops, stores the packet and startup a waiting timer. If no rebroadcast packets are received within the set time then they rebroadcast the packet by themselves. Any neighboring node receiving the broadcasted packet, adds its ID to the regular beacon, to enable other nodes to know of their neighboring nodes not receiving the broadcast packet for rebroadcasting the packets to it [2].

V. CONCLUSION

Unicast, multicast, and broadcast routing operations are vital issues in the network layer for VANETs. This work surveys existing unicast, multicast, and broadcast protocols for VANETs. The unicast routing protocols are split into min-delay and delay-bound approaches. The min-delay unicast routing protocols construct a minimum-delay routing path as soon as possible. The delay-bound routing protocol utilizes the carry-and-forward technique to minimize the channel utilization within a constrained delay time. This work also surveys important multicast and geocast protocols for VANETs. The multicast in VANETs is defined by delivering multicast packets from a mobile vehicle to all multicast-member vehicles. The geocast in VANETs is defined by delivering geocast packets from a source vehicle to vehicles located in a specific geographic region. Finally, broadcast protocols in VANETs are also introduced. The key points while designing of the routing protocols for VANETs must be the low communication overhead, the low time cost, and high adjustability for the city, highway, and rural environments.

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