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Geographical Topologies of Routing Protocols in Vehicular Ad hoc Networks – A Survey

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***Abstract*---Vehicular Ad Hoc Networks (VANETs) have grown out of the need to support the growing number of wireless products that can now be used in vehicles. These products include remote keyless entry devices, personal digital assistants (PDAs), laptops and mobile telephones. As mobile wireless devices and networks become increasingly important, the demand for Vehicle-to-Vehicle (V2V) and Vehicle to-Roadside (VRC) or Vehicle-to-Infrastructure (V2I) Communication will continue to grow.**

Vehicular Ad hoc Network (VANET), a subclass of mobile ad hoc networks (MANETs), is a promising approach for the intelligent transportation system (ITS). The design of routing protocols in VANETs is important and necessary issue for support the smart ITS. It is not effectively applied the existing routing protocols of MANETs into VANETs. In this paper, We introduce position based protocol in VANETs. It is observed that carry-and-forward is the new and key consideration for designing all routing protocols in VANETs. The temporary network fragmentation problem caused by rapidly changeable topology influence on the performance of data transmissions. The challenges and perspectives of routing protocols for VANETs are finally discussed in this article.

Keywords—Geographical topology, VANET routing protocols, position based routing.

I. INTRODUCTION

Vehicular Ad hoc networks (VANETs) are a special type of mobile ad hoc networks; where vehicles are simulated as mobile nodes. VANET contains two entities: access points and vehicles, the access points are fixed and usually connected to the internet, and they could participate as a distribution point for vehicles [1]. VANET addresses the wireless communication between vehicles (V2V), and between vehicles and infrastructure access point (V2I). Vehicle to vehicle communication (V2V) has two types of communication: one hop communication (direct vehicle to vehicle communication), and multi hop communication (vehicle relies on other vehicles to retransmit). VANET also has special characteristics that distinguish it from other mobile ad hoc networks; the most important characteristics are: high mobility, self-organization, distributed communication, road pattern restrictions, and no restrictions of network size [2]-[4], all these characteristics made VANETs environment a challenging for developing efficient routing protocols. VANETs applications types are classified into safety and efficiency application [1], [5], [6]. There are many difficulties facing VANETs systems design and implementation, including: security, privacy, routing, connectivity, and quality of services. This paper will focus on position based routing problem in vehicle to vehicle communication (V2V).

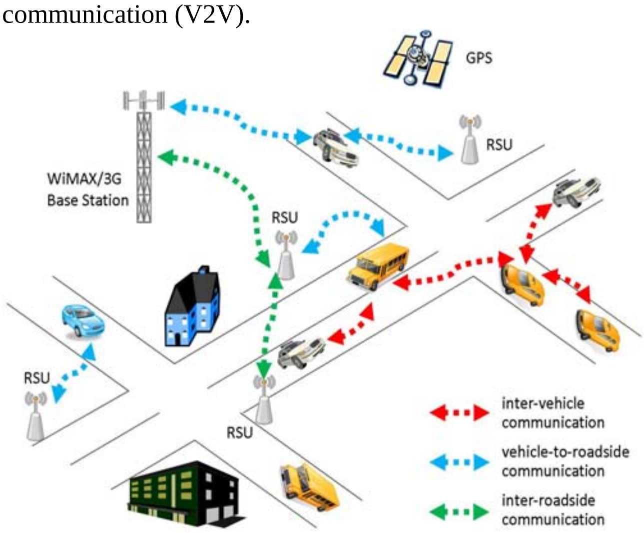

Fig 1: An Example of VANET

II. ROUTING PROTOCOLS IN VANET

The main goal for routing protocol is to provide optimal paths between network nodes via minimum overhead. Many routing protocols have been developed for VANETs environment, which can be classified in many ways, according to different 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, broadcast, and cluster-based routing protocols, this classification is based on the routing protocols characteristics and techniques used [2], [5], and [7]. 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 two classes according to routing strategies: proactive and reactive [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]. Also based on quality of services classification, there are three types of protocols that dealing with network topology (hierarchical, flat, and position aware), concerning with route discovery (reactive, proactive, hybrid and predictive), or based on the MAC layer interaction [9]. However all previous classifications did not concern by transmission strategies classification (such as unicast, broadcast, and multicast).

This paper will address only position-based routing protocols.

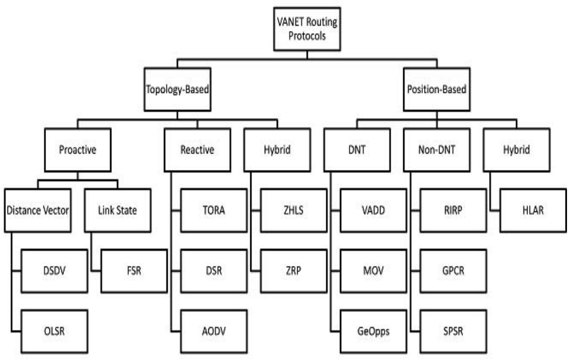

Fig 2: Hierarchy of Routing Protocols in VANET

III. ROUTING INFORMATION USED IN PACKET FORWARDING

The routing is divided into two subclasses: topology-based and position-based routing protocols. In topology-based routing, each node should be aware of the network layout, also should able to forward packets using information about available nodes and links in the network. In contrast, position-based routing should be aware of the nodes locations in the packet forwarding.

Position-Based Routing Protocol

Position or geographic routing protocol is based on the positional information in routing process; where the source sends a packet to the destination using its geographic position rather than using the network address. This protocol required each node is able to decide its location and the location of its neighbors through the Geographic Position System (GPS) assistance. The node identifies its neighbor as a node that located inside the node's radio range. When the source need to send a packet, it usually stores the position of the destination in the packet header which will help in forwarding the packet to the destination without needs to route discovery, route maintenance, or even awareness of the network topology [3], [4]. Thus the position routing protocols are considered to be more stable and suitable for VANET with a high mobility environment, compared to topology-based routing protocols.

Geographic routing protocols commonly classified into three classes:

1. Delay Tolerant Network (DTN) Protocols,
2. Non Delay Tolerant Network (Non DTN) Protocols and
3. Hybrid [4].

1. Delay Tolerant Network (DTN) Protocols

DTN is a wireless network designed to perform efficiently in networks with some characteristics; like frequent disconnection communication, large scale, long unavoidable delays, limited bandwidth, power constraints and high bit fault rates [12]. In this network, all nodes help each other to forward packets (store and forward scheme). These nodes may have a limited transmission range; so packets transmission will take large delays. Commonly, the DTN node is a mobile node, so it establishes routes to other nodes when they reach its transmission range.

In DTN protocol, there is no guarantee of unbroken end to end connectivity, so the packets may be cached for a time at intermediate nodes [4], [11], [3]. To design of a routing protocol for DTN network with these characteristics is a significant problem. This section, review many DTN routing protocols that fall under this category.

1.1 Vehicle-Assisted Data Delivery in Vehicular Ad Hoc Networks (VADD)

VADD protocol designed to handle frequently disconnected vehicular networks and highly mobility problems. It implements the store and forward scheme; while a node is moving it stores the packet, until a new node arrives to its zone range, and then it forwards the stored packet to this new node. This protocol predicts node mobility based on two factors:

Network traffic and route type; that help a node to discover the next forwarding node. VADD protocols usually deliver the packet to the path with the least transmission delay; following three main principles [4], [11]:

- Continue use the available wireless channel
- Deliver the packet to the higher speed node in the route to carry it
- VANET is a high mobility environment, so it's difficult to estimate packet delivery by a predefined optimal path, which may lead to frequent discover a new optimal path to transmit a packet.

To break the routing loop, each node adds information about its former hop/hops before forwarding the packet, containing its own information as a former hop. Once the packet received to a node, it looks at the previous hops information to avoid forwards the packet to the previous hops and try to find other available hop; so that may avoid the routing loop problem. To forward a packet, VADD implements four different schemes [4], [11]:

- Location First Probe (L-VADD): it used to deliver the packet to the closest node to the destination without consideration of the movement direction. The drawback in this scheme the occurring of the routing loop.
- Direction First Probe (D-VADD): the selection of the next hop is based on the node has the same movement direction as the destination, which helps in avoiding the route loop.
- Multi-Path Direction First is the Probe VADD (MD-VADD): it provides a multi path rather than one path; however, it consumes the bandwidth by redundancy packets.
- Hybrid Probe VADD (H-VADD): it is a hybrid scheme that takes the advantages of L-VADD and D-VADD, to deliver a packet, it initially uses the L-VADD; but if a route loop is identified, it changes to D-VADD. As a result this scheme performs better than pure L-VADD and D-VADD.

1.2 Motion Vector Routing Algorithm (MOVE)
MOVE algorithm is designed for light networks, especially for road side vehicle communication. This protocol assumes that each node has global locations information, that's beside the knowledge of a mobile router speed and its neighboring nodes velocity. From this information the node can estimate the nodes which are the closest distance to the destination [11].
In this protocol each node regularly broadcasts a HELLO message; and its neighbor replays by a RESPONSE message; by this replayed message the node will know its neighbors and their locations. Given this information, the node can estimate the shortest distance to destination, in that case the node decides how to forward the message according to the information about nodes which are currently located nearby the destination. MOVE protocol uses less memory size compared with Non DTN position-based routing; it also has a higher data transmission rate in light environments [30]. However, Non DTN position-based routing could have better performance only if the routes are stable and consistent [3].

1.3 Geographical Opportunistic Routing (GEOPPS)
GeOpps is a forwarding protocol uses the available navigation system in collecting information about geographical position; this information is used to select vehicles that are closest to a certain destination. The protocol uses store and forward technique, it works just like the Move and Non DTN protocols but it uses navigation system to provide efficient packet delivery. In the GeoOpps, to send a packet from the source to the destination, there are three main steps used to select the next hop of the intermediate nodes [3], [5]:

- Each neighboring node at the estimated routes calculates the future closest point to the destination which it will reach soon.
- Each neighbor node then calculates estimated shortest delay time to reach the specified packet's destination.
- Use the estimated shortest time calculated by each neighbor node; that any node estimated to be closer to the destination in lowest delay time, should be selected to become the next hop carrier to transmit the packet faster to the specified destination.
- The node ignores the estimated calculated route and follows other different path; in this case the system will forward the holding packet to any neighbor node.
- The node stops its movement (switch off the engine or long pause time); in this case its packets should be forward to another neighboring node.

2. **Non Delay Tolerant Network (Non Dtn) Protocols**
The non-DTN protocols are geographic routing protocols, but it does not consider a disconnectivity issue; it assumes there are always a number of nodes to achieve the successful communication; so, this protocol is only suitable for high density network. In these protocols, the node forwards its packet to the closest neighbor to the destination, but this approach may be unsuccessful if there is no closest neighbor to the destination rather than the current node itself. Many non-DTN routing protocols handle this failure; by different strategies will be shown in the following sections [1].

2.1 Greedy Perimeter Coordinator Routing (GPCR)
GPCR protocol is designed to be suitable for the high mobility environments (as in city) based on the greedy forwarding technique; this technique aims to forward the packet to a neighbor node which is closest to the location of the destination. Each node has to be aware of its location gotten by a navigation system, it knows its neighbor by periodic beaconing, and the position of the destination is obtained from the location service. When a node forwards a packet, the packet will be spread over the road until it reaches the next intersection. The maintenance process covers two components: decision making, to decide which intermediate node the packet will be passed on the intersection (a coordinator node selection), and forwarding the packet to the next intersection. The coordinator node decides to which route the packet will be forwarded. But if no coordinator node found in the route, the packet will be forwarded to furthest node [10].
GPCR does not need any global information; however it is based on the connectivity of the destination node and the density of the next roads, it could not connect the destination if the node density is low, which will increase the transmission delay [13].

2.2 Reliability -Improving Position-Based Routing (RIRP)
RIPR is a position-based routing algorithm designed for VANETs, it aims to solve the problems of links failures that found in a position-based routing; which appear due to storing old information about a stale intermediate node. RIPR predicts the vehicle speeds and their moving directions, as well as estimates the characteristics of the city road. In this protocol, the sender selects an intermediate node to forward its packet, based on the mobility estimation for neighboring nodes that done by initially deciding whether a neighbor node exists or not. The sender creates a position record for each neighboring node, this record contains the recent position of the node and its mobility speed; that helps in the selection of the forwarder node which is done based on the route characteristics and the node position record which arranged after the exchange of beacon messages.
This record avoids the local problem which prevents a node to select a neighbor node as a forwarder node; that happens because there is no node that is closest to the destination [14]. RIPR protocol is similar to GPSR protocol uses two modes: a greedy mode and perimeter mode, as well as the route characteristics consideration, and the position of the nodes. Therefore, RIPR can solve the link failure problem caused by storing information about a stale intermediate node; so it can reduce the possibility of link failure [13].

2.3 Hybrid Position-Based Routing
Position routing protocol reduces control routing overhead, it doesn't need to construct or maintain a routing table; because it only uses the location information about the neighbors and destination nodes, these issues made

position-based routing protocols scalable. However, position routing protocols have many limitations that restrict their usage; these limitations can be summarized in the following points [6]:

- The performance of position routing can be significantly decreased according to the location accuracy; because the accurate locations information is an essential factor to get a good performance in position routing.
- Position routing could be failing, if there is no any neighbor node which is closer to the destination (null area).
- Position routing solves the absence of closest neighbor toward the destination, by the backup process. However, it required packets to travel larger distances to reach destinations, also packets could be travel in a close circle, or could be dropped.

3.1 **Hybrid Location –Based Ad Hoc Routing Protocol (Hiar)**

HLAR is a hybrid position routing protocol designed to efficiently use all the available location information and to minimize the routing control overhead. This protocol is planned to switch to the on-demand routing when sufficient location information is unavailable or limited, it also deals with the problem of no closest neighbor to the destination (void regions), and so it is almost a scalable protocol. HLAR works as a reactive protocol in the route discovery process, however if there is no route to the destination node, the source node adds information about its location and the location of the destination in the route request packet then it searches for a closer node near the destination.

If the node finds a neighbor which is close to the destination then it forwards the request packet to it. But if no closer neighbor node is found, it floods the route request packet to all its neighbors. The source node repeats these steps until it reaches the desired destination. The simulation results showed that the HLAR protocol minimizes the routing control overhead compared with the on-demand routing protocols, furthermore it generally provides a fresh large size location information [6]. However, HLAR doesn't guarantee the best reliable route; because the intermediate node doesn't have a reverse link to the source, and could not inform other neighboring nodes if it finds a better route to source [15].

III. CONCLUSION

Unicast, multicast, and broadcast routing operations are key issues in the network layer for VANETs. This work surveys existing topology, and position based protocols for VANETs. The 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 multi-cast-member vehicles. The geocast in VANETs is defined by delivering geocast packets from a source vehicle to vehicles located in a specific geographic region. A mobicast routing protocol in VANETs is also described. Finally, broadcast protocols in VANETs are also introduced. We predict the tendency of the design of 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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