Global Journal of Computer Science and Technology
Network, Web & Security
Volume 13 Issue 17 Version 1.0 Year 2013
Type: Double Blind Peer Reviewed International Research Journal
Publisher: Global Journals Inc. (USA)
Online ISSN: 0975-4172 & Print ISSN: 0975-4350

Comparison among Different Routing Protocols of Vehicular Ad Hoc Networks

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GJCST-E Classification : *C.2.2*

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Comparison among Different Routing Protocols of Vehicular Ad Hoc Networks

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Abstract- To improve highway transport security, VANET (Vehicular Ad Hoc Network) is used which is a developing technology incorporating ad hoc network, cellular technology and wireless LAN. VANETs are different from other type ad hoc networks by their cross network constructions, node association features and new application setups. The approach of an effective routing protocol for VANETs is vital as VANETs show various distinctive networking research challenges. In this paper, we discuss the research challenges of routing in VANETs and compare recent routing protocols of VANETs.

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I. Introduction

Vehicular ad hoc network (VANET) is a special type of Mobile Ad hoc Network (MANET) which is designed to facilitate vehicle to vehicle (V2V) and vehicle to roadside communications. It is a promising new technology to achieve intelligent inter-vehicle communications and flawless internet connectivity by integrating the capabilities of new generation wireless networks to vehicles. Analogous to MANET it is autonomous, self-organizing and self-managing wireless communication network. Nodes in VANET involve themselves as servers and/or clients for exchanging & sharing information via shared radio transmission. Three possible network architectures for VANET are: pure cellular/WLAN, pure ad hoc, and hybrid. A simple scenario of vehicular ad-hoc network is shown in figure 1. VANET introduces Intelligent Transportation Systems (ITS) which includes a variety of applications such as co-operative traffic monitoring, control of traffic flows, blind crossing, prevention of collisions, nearby information services and real-time detour routes computation. It can be also used for providing Internet connectivity to vehicular nodes while on the move. The unique characteristics of VANET are the high nodes mobility and unreliable channel conditions which poses the problems of frequent change in network topology. So finding and maintaining routes is a very challenging task in VANETs. The existing routing protocols for MANET shows poor performance when directly applied to

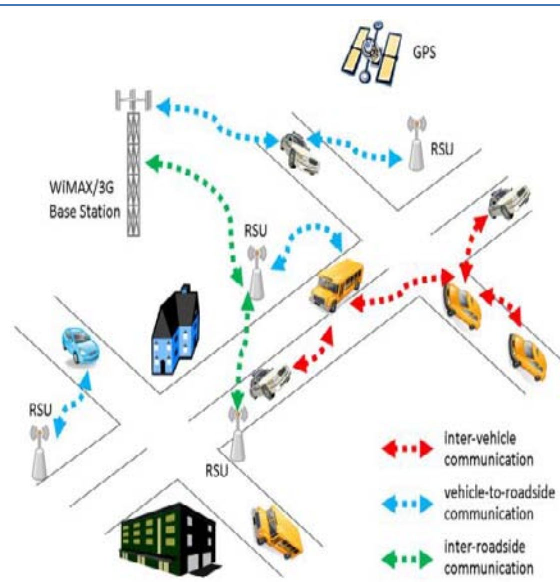

Figure 1 : Vehicular Ad Hoc Network.

VANET environment due to the fast vehicles movement and dynamic information exchange. Thus design of a suitable routing protocol to deal with the highly dynamic nature of VANET has taken significant attention. In this literature we will review the key characteristics in VANET and some of the existing routing protocols for VANET which can be used for better understanding of the routing protocols and future improvement can be made.

II. Characteristics of Vanet

VANET has some unique characteristics which make it different from other kinds of Ad hoc networks as well as challenging for designing VANET routing protocols.

a) High Dynamic topology

The topology of VANET is always changing due to the high speed and choice of path of vehicles. If we assume two vehicles moving away from each other with a speed of 60 mph (25m/sec) and the transmission range is about 250m, then the link between these two vehicles will last only for at most10 seconds.

b) Frequent disconnected Network

Due to the same reason, the nodes needed another link with nearby vehicle in about 10 seconds to maintain seamless connectivity. But in case of such failure, particularly in case of low vehicle density zone,

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frequent disruption of network connectivity will occur. One possible solution of such problems is addressed by road-side deployment of relay nodes.

c) Mobility Modeling and Prediction

Besides the highly mobile node movement and dynamic topology, vehicular nodes are usually constrained by prebuilt highways, roads and streets. So mobility model and node prediction based on study of predefined roadways model and vehicle speed is of paramount importance for effective network protocol design for VANET.

d) Communication Environment

VANET are typically operated on two communication environments: highway traffic scenario and city environment. The node prediction design and routing algorithm also therefore need to adapt for these two environments. Highway mobility model is rather simple and easy to predict than the city mobility model. Street structure, variable node density, presence of buildings and trees that behave as obstacles to even small distance communication make the city model very complex and difficult.

e) Hard Delay Constraints

Overcoming the issues of hard delay constraints are of great importance in VANET than the high data rate. For example safety aspect such as accidents or brake event the message should be transferred and arrived in a certain time to avoid car crash.

f) Interaction with onboard sensors

It is assumed that the nodes are equipped with on-board sensors such as GPS receivers. This sensors helps in providing node location and their movement nature that are used for effective communication link and routing purposes.

g) Battery Power and Storage capacity

Modern vehicles have enough computing power because of unlimited battery power and storage which is unavailable in MANET. It is helpful for effective communication & making routing decisions.

III. Routing Protocols for VANET

Routing in VANET can be classified in many dimensions. In this literature we classify them into five categories as follows: ad hoc, position-based, cluster-based, broadcast, and geo-cast routing protocols. These protocols are characterized on the basis of area / application where they are most suitable. In this section we have discussed about these protocols.

a) Adhoc Routing

Most of the characteristics of Vehicular Ad Hoc Network (VANET) are analogous to that of Mobile Ad Hoc Network (MANET). Therefore most of existing MANET routing protocols can be directly applied to VANET. Reactive routing protocols such as AODV (Ad Hoc on demand distance vector) and DSR (Dynamic source routing) are also called on-demand routing protocols as they periodically update the routing table. Reactive routing consists of route discovery phase which causes more routing overhead and also suffer from the initial route discovery process. Moreover route maintenance process in DSR does not locally repair a broken link. Simulation of these algorithms in VANET brought out frequent communication break because of the highly dynamic nodes. Therefore it becomes obligatory to suitably modify the existing protocols of MANET to meet the challenges in VANET.

i. *PRAODV/PRAODV-M:* Namboodiri et al. proposed some modifications in [1].

- A highly partitioned highway scenario is used for the network model. Therefore most path segments are relatively small.
- To reduce the ill-effects of frequent route breakages in case of AODV two new predictions-based AODV algorithms are introduced.
- First one is referred as PR-AODV and it uses node position and their speed information in AODV to predict link life time. It constructs a new alternate link before the end of estimated link lifetime. Where in AODV, the link created only after the failure of connectivity occurs.
- In contrast to selecting shortest path as in PRAODV or AODV the second modified algorithm (PRAOVD-M) computes the maximum predicted life time among various route options.
- The simulation on both showed slight improvement in packet driving ratio. However, the success of this algorithm largely depends on the prediction of node position and mobility.

ii. *AODV-bis:* Another modification is proposed in [2].

- AODV is modified to forward the route request within a zone of relevance (ZOR) from the point of event occurrence.
- ZOR can be rectangular or circular specified by the particular application.

b) Position Based Routing

Routing strategies that employs geographical information in their routing decision have been identified as more promising routing paradigm for VANET environment. These protocols use location information to select the next forwarding hops so no global route between source and destination needs to be created and maintained.

Greedy Perimeter Stateless Routing (GPSR): GPSR (Greedy Perimeter Stateless Routing) [3] is one of the best known position based routing. It takes greedy forwarding decision based on the location information of immediate neighbors. Where greedy forwarding fails it uses perimeter mode or face routing on a planarized graph of the network to find the next forwarding hop. Figure 2 shows greedy

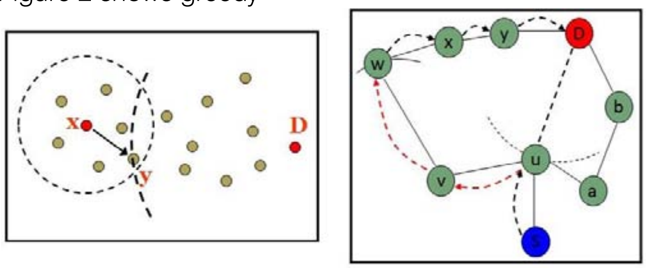


Figure 2 : (a) greedy forwarding and (b) perimeter mode forwarding.

forwarding and forwarding in perimeter mode.

- It works best in highway scenario with evenly distributed nodes.
- GPSR generally shows better performance when applied to highway scenario than that of DSR because of fewer obstacles compared with city scenario.
- GPSR has to face some challenges when applied to city scenario:
  - Greedy forwarding sometimes fails in case where direct communication between nodes does not exist due to the obstacles such as buildings and trees.
  - In perimeter mode a planarized network graph is traversed when greedy fails which create longer path resulting in higher delays and also degrade the performance
  - Due to the highly dynamic nature of nodes in VANET routing loops can be induced by the right-hand rule used in face routing
  - Moreover Packet can be forwarded in wrong direction resulting higher delays

Geographic Source Routing (GSR): Lochert et al [4] proposed GSR routing for vehicular ad hoc networks in city environments. It combines.

Figure 3 shows some examples of GPSR failures. To solve the above constraints certain improvements are made in the GPSR algorithm position-based routing with topological knowledge. This street awareness in GSR is provided by static street map and it uses Reactive Location Service (RLS) to get the destination position. GSR uses greedy forwarding along a pre-selected shortest path and this path is computed by Dijkstra shortest path algorithm.

- GSR shows better average delivery rate, smaller total bandwidth consumption and similar latency as with DSR or AODV.
- The protocol overlook the situation where the traffic density is low it is difficult to find end to end connection along a preselected path.

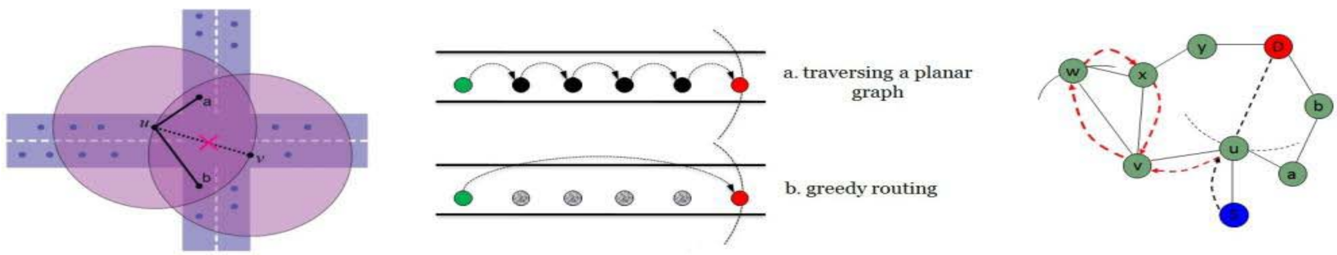
Greedy Perimeter Coordinator Routing (GPCR): Greedy Perimeter Coordinator Routing (GPCR) is proposed in [5] and it consists of two parts: a restricted greedy forwarding and a repair strategy. Unlike GSR this algorithm is based on the topology of real world streets and junctions which form a natural planar graph. Therefore it does not require a graph planarization process as GPSR or does not use any global topology information like GSR. The restrictive greedy algorithm is applied when nodes are in street and an actual routing decision is taken only at the junction of streets. So packets are forwarded to a junction node (coordinator) rather sending it across the junction. When stuck into a local minimum GPCR adopt a repair strategy. (1) Coordinator node decides using right-hand rule which street the packets should follow. (2) In between junctions greedy forwarding is applied to reach the next junction. In figure 4 restricted greedy routing and repair strategy in GPCR is shown.

There are two different approaches to detect junction nodes:

(1) by analyzing node position and the position and presence of the neighbor's neighbors from beacon messages (2) by calculating the correlation coefficient with respect to the position of its neighbors.

The simulation results using NS-2 simulator in a real city scenario shows higher delivery rate than that of GPSR with large average number of hops. But it introduces slight increase in latency.

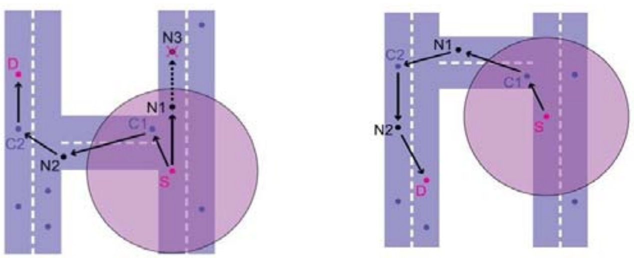
- GPCR fails to work efficiently in city scenario with high rise building, uneven concentration of vehicles on roads.



(a) Network Disconnection: link uv is removed by planarization. However, due to obstacles (such as buildings), there is no direct link ua or ub.
(b) Longer path in perimeter mode.
(c) Routing loop introduced by right-hand rule in face routing.

Figure 3 : Examples of GPSR failures

- There are problems in junction detection approaches. First approach fails in case of curve streets and second one fails for sparse streets.



(a) (b)

(a) Using restricted greedy forwarding packet is forwarded to C1 (coordinator node) from S instead of N1 (regular greedy forwarding).
(b) Repair Strategy: In node S (local minimum) algorithm switched to repair strategy. Packets forwarded to C1 (coordinator node) and it decides which road to follow.

Figure 4 : GPCR routing strategy

Anchor based street and traffic aware Routing (A-STAR): Anchor-Based Street and Traffic Aware Routing [6] (A-STAR) is a position based routing protocol which is specially design for city scenarios for inter vehicle communication system. But unlike GSR, A-STAR takes into account both street and traffic awareness in computing the anchor paths. A-STAR integrates traffic awareness by using vehicular traffic city bus information to identify an anchor path with high connectivity for packet delivery. An anchor path can be computed using Dijkstra's least-weight path algorithm. Traffic awareness can be incorporated by using either statistically rated maps or dynamically rated maps. A-STAR employs a new local recovery strategy for packets that stuck into a local minimum which is more suitable for a city environment than the recovery strategies used in GPSR and GSR. A new anchor path is computed from the point of local minimum and the packet is routed through this new anchor path. The street at which local minimum is occurred is marked as "out of service" temporarily.

- A-STAR shows the best performance compared to GSR and GPSR, because it can select paths with higher connectivity for packet delivery. As much as 40% more packets are delivered by A-STAR compared to GSR.
- A-STAR guarantees for finding an end-to-end connection in case of low traffic density. The subscript for the permeability of vacuum □0, and other common scientific constants, is zero with subscript formatting, not a lowercase letter "o."

c) *Geocast Routing*

Geocast routing protocols follow the standard of routing data packets from a single source vehicle to all vehicles fitting to the destination area called zone of relevance ZOR. This multicast routing protocol can be implemented by simply defining the multicast group within the ZOR. Geocast routing follows a directed flooding strategy within a defined forwarding area, zone of forwarding ZOF so that it can limit the message overhead and network congestion of simple flooding. Figure 5 illustrates the ZOR in Geocast routing. The message is first forwarded from the sender to the geographic area via unicast. It is then simply broadcasted to all vehicles inside the target region. So identify the zone of relevance is important in Geocast routing. IVG, Cached Geocast, Abiding Geocast, DRG, ROVER, DG-CastoR, Mobicast, DTSG, Constrained Geocast, and Geocache are some existing Geocast routing protocols in VANETs. In this literature IVG, ROVER and Abiding Geocast are discussed.

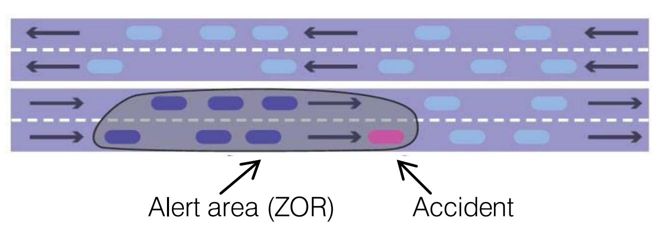


Figure 5 : Geocast routing.

Inter Vehicles Geocast Protocol (IVG): Bachir and Benslimane in [7] proposed a Geocast protocol named Inter-Vehicles Geocast (IVG).

- IVG works by informing the vehicles located in a risk area, which formed a multicast group about any danger on the highway. A message alert is broadcasted to the multicast group by the damaged vehicle.
- The precise obstacle location and the driving directions are taken into account in determining the risk area.
- Neighbors inside the risk area calculate a differ time backoff that helps the furthest node to relay rebroadcasting the message. Figure 6 shows an example of relay selection in IVG.

RObust Vehicular Routing (ROVER): ROVER [8] proposed by M. Kihl and al. is a protocol which is similar to AODV. It broadcasts only the control packets & data packets are unicasted. ROVER assumptions are:

- Each vehicle has an Identification Number,
- Each vehicle should have a GPS receiver,
- Vehicles must have access to a digital map,
- ZOR is a rectangle area and within ZOR reactive route discovery process are used,
- ZOF includes the sender and the ZOR.

The goal of ROVER is to deliver an application generated message to all vehicles those are located into the specified ZOR. A lot of redundant messages is created by this protocol which caused in network congestion and high delay in data transfer.

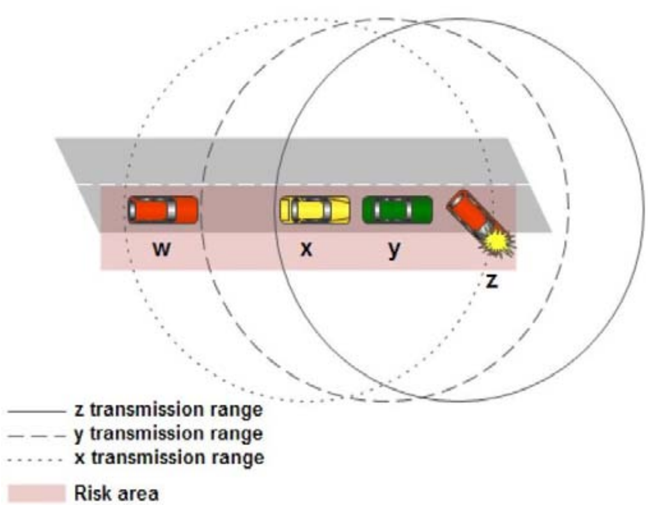


Figure 6 : IVG Relay selection: x is more distant to z then y. x is a relay. x permits to reach w while y not

Abiding Geocast: Abiding Geocast [9] was proposed by Maihöfer and Eberhardt. It allows a continuous delivery of a Geocast message in Ad Hoc Networks. Three solutions are provided for Abiding Geocast:

1. Using a server that stores Geocast message. Main objective of this server is to use a Geocast protocol that periodically delivers the Geocast message to the destination zone.
2. A node is nominated in the appropriate destination area in order to store the Geocast message and periodically or by notification retransmit it.
3. The neighbour approach allows all nodes to store the Geocast message.

- *Uses of abiding Geocast:*
- Advertising or informing drivers about the state of the road. (slippery surface, ice storm, etc.)
- Elected node approach and neighbour approach are more improved for safety applications to inform drivers about an accident on their way.

d) Cluster Based Routing

In cluster-based routing scalability is provided by creating a virtual network infrastructure through the clustering of nodes. Figure 7 illustrates a cluster-based routing.

Cluster is represented by a cluster head. Inter-communication between different clusters is carried through cluster heads. Intra-communication within each cluster is made through direct link. The current cluster-based protocols in MANET are not stable in vehicular ad-hoc network because of their short-life.

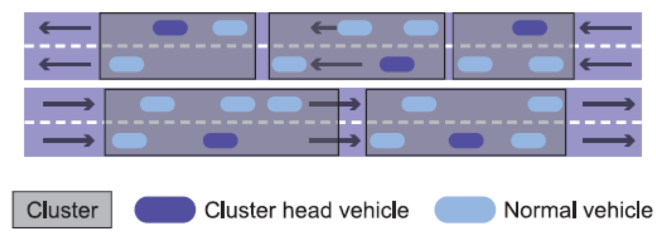


Figure 7 : Vehicles form multiple clusters in cluster-based routing.

Some Cluster-Based Routing protocols in VANETs are: COIN, LORA_CBF.

COIN: Clustering for Open IVC Networks (COIN) algorithm is proposed by Blum et al. [10]. Cluster head election is constructed on vehicular dynamics and driver purposes, instead of ID or relative mobility. This algorithm shows the oscillatory nature of inter-vehicle distances.

- COIN increases the average cluster lifetime by at least 192% and reduces number of cluster membership changes by 46%.

LORA_CBF: LORA_CBF is a reactive location based routing algorithm proposed by Santos et al. [11]. It uses cluster-based flooding for VANETs.

- Any node can be the cluster- head, gateway or cluster member.
- Every cluster has exactly one cluster-head.
- A node connected to more than one cluster is called a gateway.
- The cluster-head preserves information about its members and gateways.
- Packets are forwarded using greedy routing. If the location of the destination is not available, only the

cluster-heads and gateways will propagate the LREQ (Location Request) and LREP (Location Reply) messages.

The performances of LORA_CBF, AODV and DSR are evaluated in typical urban and highway traffic scenarios. The results show that network mobility and size affect the performance of AODV and DSR more ominously than LORA_CBF. Cluster-based routing protocols can achieve good scalability for large networks. A major obstacle for the protocols is fast-changing VANET systems, the delay and overhead involved in creating and preserving these clusters.

e) Broadcast Routing

Regularly used routing scheme in VANETs is Broadcast. Broadcast is used for sharing information about crisis, street situations, advertisements etc. Efficient route exploration in unicast protocol is another usage of Broadcast routing. Easiest technique to apply broadcast is flooding. Flooding enables every node to forward the incoming message to its entire neighbours except its parent node. Flooding works efficiently in small networks. But efficiency decreases for larger networks.

BROADCOMM: The freeway is separated into virtual cells in BROACOMM [12]. In BROADCOMM, movement of virtual cells are based on the movement of vehicles. All the vehicles of freeway are classified in two groups.

Figure 7. Vehicles form multiple clusters in cluster-based routing.

1. All the vehicles in a cell
2. Small number of vehicles situated closely to the centre of the cell, called cell reflectors.

BROADCOMM works better than analogous flooding based protocols for message broadcasting delay and routing overhead. The drawback is, it is only applicable for simple freeway networks.

Urban Multi-Hop Broadcast protocol (UMB): Urban Multi-Hop Broadcast protocol (UMB) [13] is proposed to transmit messages in urban areas. There are some issues related to urban area such as interference, packet collisions and hidden nodes problems due to multihop broadcast. There are two steps in UMB:

1. Directional Broadcast: Transmitting node picks the furthest node in broadcast direction without any topology information. Selected node has the responsibility of next forwarding.
2. Intersection Broadcast: Repeaters are installed in every intersection point. Repeaters re-broadcast the packets to all road segments except the receiving direction.

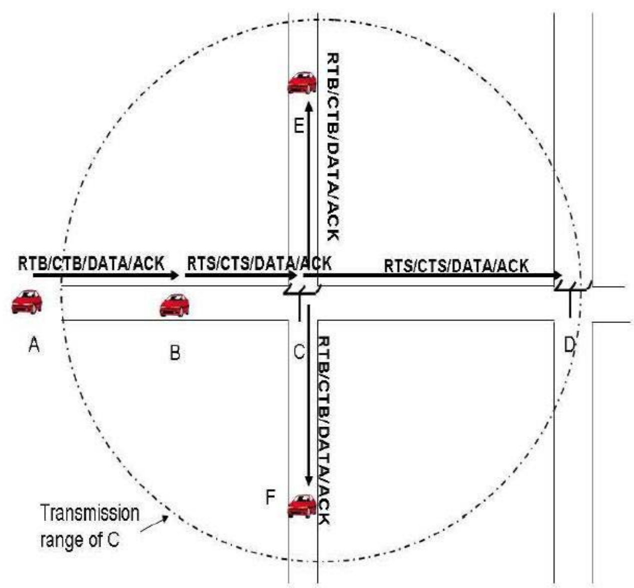


Figure 8 : UMB protocol

For dense networks and high packet loads, UMB protocol has higher success rate than 802.11-distance and 802.11-random protocols.

Vector-based TRAcking DEtection (V-TRADE): V-TRADE [14] is a GPS based message broadcasting protocol which is similar to the unicast routing protocol Zone Routing Protocol (ZRP) [15]. Neighbours are classified into different forwarding groups based on position and movement information. Border vehicles which are small subset of vehicles from each group are selected to forward the message. V-TRADE selects small number of vehicles to forward the messages. This feature utilizes bandwidth. Reachability decreases slightly due to small number of forwarding vehicles.

f) Comparison of routing protocol in VANET

Table 1 summarizes the characteristics of routing protocols in VANET.

Table 1 : Comparisons of Routing Protocols In Vanets

Routing Protocols	Routing Type	Position Information? (How to use)	*Hierarchical structure*	Network Simulator	Simulation Scenario
AODV	Unicast	No	No	---	---
DSR	Unicast	No	No	---	---
GPSR	Unicast	Packet Forwarding	No	---	---
PRAODV/ PRAODV-M	Unicast	Route Selection (lifetime prediction)	No	NS2	Simple highway model (20km segment only)
AODV-bis	Unicast	Route-Req Forwarding	No	---	---
GSR	Unicast	Packet Forwarding	No	NS2	Real city model (from map)

GPCR	Unicast	Packet Forwarding	No	NS2	Real city model (from map)
A-STAR	Unicast	Packet Forwarding	No	NS2	Grid city model
COIN	Unicast	Cluster Formation	Yes	Own	Real highway model
LORA_CBF	Unicast	Packet Forwarding	Yes	Opnet	Simple circle and square road
Flooding	Broadcast	No	No	---	---
UMB	Broadcast	Packet Forwarding	No	Own	Simple intersection road
V-TRADE/ HV-TRADE	Broadcast	Classify forwarding Group	No	Own	Simple intersection
BROADCOMM	Broadcast	Formation of Cells	Yes	Own	Simple highway model (15
Msg Dis Protcl	Geocast	Packet Forwarding	No	Own	Simple highway model (10 km)
IVG	Geocast	Packet Forwarding	No	Glomosin	Simple highway model (10 km long, 100/200 nodes)
Cached Geocast	Geocast	Packet Forwarding	No	NS2	Quadratic network (size from 1 km
Abiding Geocast	Geocast	Packet Forwarding	No	---	---

IV. Limitations and Future Perspectives

There are some observations after surveying the existing protocols for VANET.

- Most of the routing protocols in VANET perform better for a specific street condition or environment. But to provide an efficient routing, scalability should be considered which is very difficult in VANET environment.
- An efficient routing protocol for VANET must be able to communicate under low network density. The network density is usually low in off-peak hour in the city scenario or in the highway; however, the broadcast message is still necessarily need to disseminate to all vehicles in a network.
- Most of the protocols in VANET do not consider the direction of the vehicles in the road. But due to the high speed and choice of path of vehicles sometimes packets may get forwarded to the wrong direction leading higher delays or even network partitions.
- Moreover there is no agreed-upon standard or mobility model to validate their performance. For example GPSR is a widely known position based routing protocol. But the position-based routing keeps advancing into many subareas in VANETs. So evaluation of the protocols using GPSR is no longer a reasonable comparison.
- Security is also an important issue for routing in VANETs, because many applications will affect life-or-death decisions and illegal tampering can have devastating consequences. The characteristics of VANETs make the secure routing problem more challenging and novel.

A possible future work is to design an efficient routing protocol for comfort and safety applications with delay-constraint and delay-tolerant capabilities and low bandwidth utilization.

V. Conclusion

Vehicular Ad Hoc network exhibits very different characteristics from MANETs. So the existing routing protocols for MANET shows poor performance when directly applied to VANET environment. In this literature, we survey on several routing protocols proposed for VANETs. From the survey it is clear that the position-based routing and Geocast routing property. The performance of a routing protocol in VANETs perform better than other routing protocols because they support geographical property. The performance of a routing protocol in VANETs depends on various facts like mobility model, driving environment, vehicular density & many other issues. There are still lots of area where VANET can be improved or more research can be done.

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