

# A Survey and Challenges in Routing and Data Dissemination in Vehicular Ad-hoc Networks

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**Abstract**—In this paper, we survey recent results in VANET data dissemination. We structure the survey into three broad categories: geocast/broadcast, multicast, and unicast approaches; and describe key ideas of representative technologies in each category. In addition, we consider location service and security issues that are crucial for data dissemination in VANET. We conclude by sharing our thoughts on further challenges.

## I. INTRODUCTION

Vehicular communications have been considered to be an enabler for numerous vehicle safety and information applications. Many automobile manufacturers are in different stages of integrating communication devices in their vehicles for the purpose of safety, assisted driving, entertainment, and mobile commerce. As increasing number of vehicles start getting equipped with communication capability, large scale ad-hoc networks can be envisioned in the foreseeable future.

Numerous projects worldwide, e.g. [1], [2], [3] in Europe, [4] in the U.S and [5] in Japan are actively engaged in researching and developing the infrastructure for vehicular communications and applications.

Through vehicular ad-hoc networks (VANETs), it would be possible to achieve flexible communications among vehicles and with roadway or infrastructure. Multi-hop data dissemination capability is one of the major advantages of VANET. Multi-hop dissemination can be used for extending the reach of safety and emergency warning messages, exchanging neighborhood information queries, or relaying data from the Internet, etc. Accordingly, multi-hop data flows in a VANET could result from a range of applications and can have a major influence on the design of the data

dissemination technologies. Multi-hop data dissemination requires in general (1) the knowledge of node locations, and (2) a method of forwarding packets toward their destinations. This may be accomplished by two types of technologies, (a) a routing protocol that performs both functions (maintaining the network topology and forwarding packets along shortest paths), or by (b) a combination of location service and a method of packet forwarding. The choice and design of the dissemination technology should be made to match the vehicle application needs, vehicle mobility, and communication assets. We survey both types of data dissemination technologies in this paper.

We organize this paper as follows. Section II describes the geocast and broadcast methods. In Section III, we describe the multicasting protocols that have been proposed for vehicle-to-vehicle (V2V) communications. In Section IV, we discuss unicast dissemination methods. We discuss security considerations in Section V. Section VI concludes the article.

## II. GEOCAST AND BROADCAST

In this section, we present works related to broadcasting in VANETs. The primary objective of broadcasting in VANETs is to distribute information from a source to many unknown/unspecified destinations. Broadcasting is a necessity for VANETs not only for forwarding but also for delivering information without constructing a data path. Because of the multi-hop nature of vehicular networks, flooding is a fundamental mechanism to implement the multi-hop broadcasting. Various broadcast and flooding protocols [6], [7], [8], [9] have been proposed and evaluated in terms of

their reliability. Message dissemination using local attributes have been widely studied, e.g. position and direction [10], broadcast interval [11], and roadway segments [12].

Unfortunately, flooding in many cases, especially in a dense network, introduces significant communication overhead due to redundant re-broadcasting. To alleviate the well-known broadcast storm problem, most of broadcasting protocols developed for vehicular networks include efficient flooding methods; i.e., only a limited number of nodes relay the broadcasting data. In this section, we cover a part of the multi-hop broadcasting studies which are closely related to vehicular networks. Interestingly, almost all broadcasting methods in VANET utilize position information - the position information is used to identify the next relay node. We start with generic broadcasting where all connected nodes are recipients; and close this section with geocasting which is a special case where nodes in a certain geographic location are destinations.

Vector-base TRACKing DETection (V-TRADE) by Sun et al. [13] is one of the earliest examples of broadcasting in VANETs. A vehicle classifies its neighbors into multiple classes based on the position and the moving direction. A relay node selects one border node for each class and broadcasts a packet with IDs of the border vehicles. The feasibility is limited due to the excessive control overhead to collect neighboring vehicle positioning information including vehicles travelling in the opposite direction. UMB (Urban Multi-hop Broadcast) [7] segments the road in the direction of dissemination and selects next relay node in the farthest segment with RTS/CTS-like signaling. AMB(Ad-hoc Multi-hop Broadcast) [14] is a refined version of UMB. Instead of using repeaters at the intersections, AMB implements ad-hoc branching using closest relay vehicle to the intersection. Mariyasagayam et al. [15] proposed enhanced Multi-Hop Vehicular Broadcast (MHVB) protocol which is another position-based flooding scheme. MHVB defines a backfire area and if a node is in the backfire area, it does not relay the broadcast packet. Given the regional information of source and destination, and road map, Wu et al. [16] proposed MDDV (Mobility-Centric Data Dissemination Algorithm) which forwards broadcast

packets in an opportunistic manner. MDDV calculates the forwarding trajectory to the destination region, and the closest vehicles to the destination within the forwarding trajectory participate in group forwarding. The group is maintained based on the vehicle location and the forwarding trajectory. Fasolo et al. [17] developed Smart Broadcast (SB) which is similar to UMB without intersection considerations. The major difference of SB is that it assigns contention windows based on the position of vehicles relative to the source. As a result, the message propagation speed is higher in SB as compared to UMB, specifically as the vehicle density increases.

### III. MULTICAST

A number of safety applications require communications to a group of vehicles and not just pair-wise communications as supported by unicast protocols. Efficient group communications applies to vehicles requiring notification of safety information such as intersections, road blocks and high traffic density, accidents, dangerous road surface conditions, etc. Thus, for V2V communications, multicast or broadcast schemes may be more applicable than unicast protocols. For this survey, we classify multicasting technologies, which can be applicable to V2V network environments, into two main categories: topology-based and location-based approaches.

#### A. Topology-based approaches

Topology-based approaches select forwarding nodes based on the network topology information. A multicast tree or mesh is formed through a query-reply type of sequenced operations: a join-query is flooded and then join-replies are responded toward the source for the join-query. A group of members can be defined by a unique and logical group identification such as a class-D IP address: usually a multicast group is not constrained by a particular location.

ODMRP [18] generates a source-based multicast mesh, but multicast packets are forwarded based on the group address (e.g., destination IP address) rather than the sources of the packets. It is on-demand: A multicast mesh is created only when a multicast source has multicast packets to send. Also, it does not require

any underlying unicast routing protocol. MOLSR [19] is similar to ODMRP. The difference is that MOLSR uses the underlying unicast routing protocol to set up source-based multicast trees and forwards multicast packets based on both the source and group addresses of a multicast session. Because of the reactive nature of these protocols, less control overhead is generated for maintaining multicast trees; but the first few packets, which are disseminated during the phase of forming a multicast tree, experience some delay and packet loss. Such delay and packet loss may not be acceptable especially for V2V safety and emergency applications which require fast and reliable dissemination of information.

MAODV [20] generates a group-based multicast tree. It requires AODV, the underlying unicast routing protocol, during the formation of multicasting trees. Even though AODV is an on-demand unicast routing protocol, MAODV is proactive instead of on-demand. Although there is no multicast source, a multicast tree is formed as long as there is any multicast receiver. While ODMRP, MOLSR, and MAODV were developed for MANET environments, GHM [21] was designed for VANET environments. It is proactive and generates group-based multicast meshes through periodic exchange of heartbeat and membership-report messages. The number of message exchanges does not depend on the number of multicast sources as well as the number of multicast groups, which is a significant advantage of GHM. A suppression technique is applied to both control and data planes to reduce control and forwarding overhead. Reference [22] investigated the performance of GHM in perspectives of network scalability, protocol efficiency and safety application on highway environments by comparing it with MAODV, ODMRP and flooding. GHM performs better than those protocols in V2V network environments. According to [22], although MAODV provides a reasonably good delivery ratio due to proactive and group-based multicast tree, it suffers from long delays due to link-breakage detection and recovery, route recovery operation, and unicast operations which may not be necessary in vehicle network environments.

## B. Location-based Approach

Location-based approaches select forwarding nodes based on location information such as the position of a packet sender, the position of a receiving node, the positions of neighborhood nodes, and/or the coordinates of a multicast region. Since forwarding nodes are selected during dissemination of each multicast packet, location-based approaches are reactive and do not need to maintain multicast trees - no control overhead is generated. They can be further divided into two schemes: approaches with location-independent and location-dependent multicast membership based on whether the recipients are defined through the use of location information.

We first discuss the approach with *Location-independent multicast membership*. PBM [23] requires location service (i.e., analogue of domain name service used in the Internet) to find the positions of destinations. In PBM, forwarding nodes are selected based on information about both positions of all one-hop neighbors, and positions of all individual destinations (i.e., group members) which are carried in every packet header. This may not be suitable for highly mobile and dense V2V networks in which positions of vehicles rapidly keep changing and many vehicles happen to be multicast recipients: information about the positions of vehicles becomes invalid time to time due to mobility of vehicles, and the size of a packet header would be significantly increased for carrying the position information of many recipients, which results in lower packet utilization and more packet processing as well. Accordingly, delay for packet dissemination would increase. In order to cope with the drawback of PBM caused by many recipients, SPBM [24] introduced hierarchical group membership management. The network is subdivided by hierarchical levels: A geographical region in the network can be identified by a particular combination of hierarchical levels. The multicast members in geographical regions are aggregated into hierarchical levels. The hierarchy information is carried in the packet header instead of the list of position information about all destinations. RSGM [25] is similar to SPBM in the sense that the network is divided into geographical zones and multicast members are maintained through regional

group membership management, but it applies position-based unicasting to forward multicast packets.

We now discuss the approach with *Location-dependent multicast membership*. In LBM [26], a multicast group is specified by a particular area of region called a multicast region, and vehicles within the multicast region automatically become members of the multicast group. LBM uses information about a multicast region as destination information for multicast packets instead of information about positions of all individual destinations as used in PBM. Thus, in LBM, forwarding nodes are selected based on the position of a source and the coordinates of the multicast region. It employs a direct flooding method which limits the forwarding space for multicast packets. That is, all nodes within a forwarding zone between the source and the multicast region are responsible for forwarding multicast packets. For enhancement, LBM uses location information to partition the forwarding zone into grids and elects one forwarding node within each grid to forward packets from the source to the multicast region. RBM [27] and IVG [28] are similar to LBM and focus on V2V network environments: They handle a specific case of multicast region which defines a multicast scope for safety warning messages in a roadway environment. They use a flooding method with DDT (distance differ time) to disseminate the warning messages to vehicles (i.e., multicast members) within the multicast region. In that sense, they are considered as broadcasting protocols for V2V communications.

#### IV. UNICAST PROTOCOLS

Unicast routing in VANETs is significantly complicated owing to the partitioned nature of the networks resulting in highly unstable paths [29]. Various attempts [29], [30] have been made to enhance MANET routing protocols by leveraging direction prediction and vehicle heading to improve performance in the case of VANETs. These methods utilize GPS information to predict route breakages and take preemptive action. CarNet [31] proposes a scalable location service and uses it to forward packets using a geographic forwarding scheme.

For *end-to-end communication*, various position based forwarding protocols [32], [33] have also been

proposed for vehicle ad hoc networks. Position-based routing consists of 1) a location service [34], [35] which maps node ID (IP address) to geographical position (GPS); 2) and a forwarding scheme which selects the next hop based on the geographical information of the node, neighbors, destination, and other mobility parameters.

The forwarding methods share the basic route discovery philosophy with GPSR [36]. GPSR utilizes a greedy strategy to obtain routes. When stuck in a local optimum, it uses a perimeter backtracking method. A requirement for this method is that the graph must be planar. Extending this in the context of vehicular networks, authors in [32] point out that roadway networks in city scenarios are inherently planar. Using this observation, they propose a forwarding method GPCR, where vehicles at junctions decide how to forward the packets. The packet delivery ratio performance of GPCR is improved in GpsrJ+ [37] by predicting the road segments on to which the junction nodes forward packets to. Vehicle assisted data delivery (VADD) [38] forwards packets based on predicted roadway delays in a connected region. Minimum Delay Forwarding (MDF) [39] extends this notion to calculate forwarding paths that provide the minimum end-to-end delay in a distributed manner. Modified versions of topology based routing such as modified AODV [40] incorporate vehicle speeds and other GPS parameters in routing decisions.

Due to the dynamic nature of VANETS, it is difficult to justify the overhead of maintaining a location service in order to support unicast routing. Applications of V2V unicast routing in VANETs still remain unclear, specifically owing to the rapid development in the network infrastructure that can provide an alternative for supporting such communications.

#### V. SECURITY CONSIDERATIONS

Securing forwarding and dissemination is a critical issue in VANETs. Although various encryption techniques can protect the dissemination message itself, the message may not be forwarded correctly due to the multi-hop nature of VANETs. According to [41], attackers could be insider or outsider, malicious or rational, and active or passive. In VANETs, routing and

dissemination security issues could be divided into two categories: general attacks and position-related attacks.

General attacks, which happen to both topology-based and position-based forwarding solutions, include denial of service (DoS) attacks, black hole attacks, and bogus information attack, etc. DoS attack aims to bring down the VANET through methods such as channel jamming and aggressive injection of dummy messages. Black hole attack or selective forwarding is carried through a node that has the ability to lure all data around an area through itself, then simply discards all data or only forwards portion of received data. In bogus information attack, attackers diffuse false information to misguide other vehicles. General attacks except DoS attack could usually be prevented or detected by authentication. Raya and Hubaux proposed a Public Key Infrastructure (PKI) solution [41] to authenticate sessions for either forwarding information exchange or data service transmission. IEEE 1609.2 [42] also provides a similar public key certificate to protect applications.

Position-related attacks include location falsification and sybil attack [43]. Position-based forwarding is susceptible to such attacks owing to its reliance on position information. A node can claim a faked position to pretend to be optimal than other candidates to aggregate all data as a black hole. On the other hand, a node can also create a number of virtual clones, and each claims a faked position to gain a high probability to be selected as the data forwarder. To detect false position claim, autonomous position verification [44] treats VANET nodes as a number of independent software sensors, such as map-based sensor, overhearing sensor and uses acceptance range threshold, mobility grade threshold, maximum density threshold, to give an estimation of the trustworthiness of other node's position claims. Yan et al. [45] proposed to use on-board radar to detect neighbor nodes and confirm announced coordinates. Radar detection can provide higher accuracy but require extra hardware on vehicles. For sybil attack, reference [43] found that the use of bi-directional antenna could help to detect sybil attack.

## VI. CONCLUSIONS

In this paper, we have discussed recent results for data dissemination in VANETs. The dissemination methods are structured as Geocast/Broadcast, Multicast and Unicast methods. Despite the vast body of research, the topic of data dissemination continues to be challenging. It is evidently hard for a single protocol to maintain a constant performance behavior against such dynamic network. For example, for a sparse network a blind-flooding method would be a good choice, but not for a dense network. There is a need to design dissemination techniques that are flexible to dynamic situations in VANETs. Other major hurdles are the difficulty of maintaining a location service for position-based approaches and enforcing data dissemination methods from a security standpoint. The involvement of the network infrastructure may need further consideration for developing efficient V2V communications.

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