Routing Protocols for Vehicular Adhoc Networks (VANETs): A Review

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ABSTRACT

Routing in Vehicular Ad hoc Networks is a challenging task due to the unique characteristics of the network such as high mobility of nodes, dynamically changing topology and highly partitioned network. It is a challenge to maintain reliable, continuous and seamless communication in the presence of speeding vehicles. The performance of routing protocols depends on various internal factors such as mobility of nodes and external factors such as road topology and obstacles that block the signal. This demands a highly adaptive approach to deal with the dynamic scenarios by selecting the best routing and forwarding strategies and by using appropriate mobility and propagation models.

In this paper we review the existing routing protocols for VANETs and categorise them into a taxonomy based on key attributes such as network architecture, applications supported, routing strategies, forwarding strategies, mobility models and quality of service metrics. Protocols belonging to unicast, multicast, geocast and broadcast categories are discussed. Strengths and weaknesses of various protocols using topology based, position based and cluster based approaches are analysed. Emphasis is given on the adaptive and context-aware routing protocols. Simulation of broadcast and unicast protocols is carried out and the results are presented.

Keywords: Adaptive routing, Intelligent Transportation System, ITS, Mobile Ad hoc Network, MANET, Routing Protocol, Vehicular Ad hoc Network, VANET and Wireless Network

1. INTRODUCTION

Vehicular Ad hoc Networks (VANETs) are special kind of Mobile Ad Hoc Networks (MANETs) that are formed between moving vehicles on an as-needed basis. VANET is an emerging technology, which enables a wide range of applications, including road safety, passenger convenience, infotainment and intelligent transportation [1]. They help to create safer roads by disseminating information regarding the road conditions and traffic scenario among the participating vehicles in a timely manner. Along with the safety applications, VANETs disseminate valuable, real-time information to the users such as transit systems, weather information, mobile e-commerce, internet access and other multimedia applications. VANETs enable automated highway applications, where the vehicles are able to cruise without the help of their drivers, even though such applications have not yet become realistic [2].

VANETs inherit some of the characteristics such as mobile nodes and self-organizing behaviour from MANETs. However, VANETs possess certain unique characteristics such as high mobility of nodes, time-varying density of nodes, frequent disconnections, highly partitioned network and dynamically changing topology, which makes them more challenging [3]. It is a challenge to construct networks between vehicles and ensure reliable, continuous and secure communication among the vehicles in motion. Routing in VANETs is a key issue. This paper focuses on the issues related to routing in VANET environment and presents a detailed review of various routing protocols for vehicular ad hoc networks. The rest of the paper is organised as follows. Section 2 discusses the issues of routing in VANETs. Section 3 presents taxonomy on VANETs routing and Sections 4 to 8 review protocols belonging to unicast, broadcast, multicast, geocast, clustering, adaptive and context-sensitive routing protocols for VANETs. Section 9 presents the simulation results and finally Section 10 concludes with a discussion.

2. ISSUES OF ROUTING IN VANETS

Even though VANETs are capable of enabling many novel applications, the design of effective inter-vehicular communications remains as a challenge. The nodes in VANETs are themselves formed by vehicles with high mobility. Nodes in VANETs join and leave the network frequently, which results frequent path disruptions. The time varying vehicle density results in a rapid change in topology, which makes preserving a route a difficult task. This in turn, results in low throughput and high routing overhead. The well-known hidden terminal problem [4] affects the performance in VANETs causing low packet reception rate. Interference from the high-rise building induces problems such as routing loops and forwarding in wrong direction, which increases delay. The issue of temporary network fragmentation and the issue of broadcast storm [5] further complicate the design of routing protocols in VANETs. The routing protocols in VANETs should be capable of establishing the routes dynamically and maintaining the routes during the communication process. They should be capable of discovering alternate routes quickly on-the-fly in the event of losing the path.
Real-time applications and safety related applications demand strict time delay during communication. The design of routing algorithms should identify optimal paths to reduce delay in routing. Multiple routes within a network are required to avoid congestion. The key challenge is to design routing protocols to overcome these problems and to provide communication with minimum delay and with minimum overhead. VANETs allow vehicles to form a self-organizing and self-managing network in a distributed fashion without a central authority or a server dictating the communication. It is obvious that the success of VANET applications greatly depend on the routing algorithms applied. Better paradigms are required for information dissemination within the estimated time by designing efficient routing algorithms.

3. TAXONOMY OF ROUTING IN VANETS

The existing routing protocols of MANETs are studied in the context of VANETs but they cannot be directly applied due to the distinct characteristics of VANETs. The performance of VANETs routing protocols depends to a great extent on many internal and external factors. As discussed earlier, the internal factors include mobility of nodes, highly partitioned network and network path disruption. Whereas, the external factors include road trajectories, traffic conditions, environmental factors and obstacles such as high rise buildings and trees. The density of vehicles and the interference characteristics depend on the type of driving environment. The protocol should perform well in both dense and sparse traffic scenario and in both city and highway environment. One favorable characteristic of VANETs is the patterned mobility of the nodes along with the road topology, which enables the prediction of the direction and speed of the moving vehicles. This could be exploited to improve the performance of the routing protocols by developing an appropriate mobility model. A taxonomy, based on the key attributes such as network architecture, applications supported, routing strategies, forwarding strategies, mobility models and quality of service metrics, is developed and presented in Figure 1.

VANETs enable a gamut of applications including cooperative collision warning, post-crash notification, road hazard control notification, congested road notification, etc., together forming Intelligent Transportation System (ITS). A universal routing solution for all VANETs application scenarios may not be viable. Design of VANETs routing protocols is a multi-faceted problem, in which one has to decide the appropriate environment and network architecture to suit the application in hand. While designing the routing protocol, one has to select appropriate routing and forwarding strategies and apply suitable mobility and propagation models to improve the performance of routing algorithms and to achieve the required Quality of Service (QoS) metrics. The challenge also lies in designing VANETs as a self-organizing and self-managing system to provide reliable and continuous service in spite of moving nodes.

VANETs enable inter-vehicular communication such as Vehicle-to-Vehicle (V2V) and communication via roadside access points such as Infrastructure-to-Vehicle (I2V) and Vehicle-to-Infrastructure (V2I) [6]. V2I or I2V provides better service in sparse networks and long distance communication; whereas V2V enables direct communication for small to medium distances and at locations where roadside access points are not available. The architecture for VANETs can be either of pure cellular/WLAN or pure ad hoc or hybrid architectures.
Within the network, communication can flow in a multi-hop fashion, where packets travel between multiple consecutive vehicular nodes to reach the destination [7]. In virtual backbone architectures some of the nodes are selected to form a backbone, which store information about the location of the dynamically changing nodes [8]. Another commonly used architecture for communication is cluster based, where a group of nodes form a cluster. One node from each cluster is designated as a cluster head, which maintains the cluster as well as manages the inter-cluster communication.

VANET routing protocols broadly fall into the following categories: unicast, broadcast, multicast, geocast and hierarchical. Routing strategies could be either proactive, which follows mostly table driven approach or reactive, where routes are discovered on-demand using on-the-fly techniques. These protocols are discussed in detail in Section IV. Mobility models help to determine the location of nodes in the area of interest at a given time. They use either macroscopic model, where the major constraints for motion such as streets, buildings, traffic lights, etc., are considered, or microscopic model, where the major constraints of motion with respect to an individual vehicle such as neighbouring vehicle, pedestrians, driver habit, etc., are considered [9].

Applying mobility model yields the following benefits: 1) a more precise view of the entire network topology as the nodes move; 2) a more precise view of the location of the individual nodes; 3) ability to predict with reasonable accuracy the future location of nodes; and 4) ability to switch over to an alternate route before a link is disrupted. In addition, routing protocols try to incorporate external sources of information such as digital maps, positioning systems, location services or even schedules of public transport to improve their performance [10].

The following sections present a detailed discussion on the routing protocols for VANETs. More detailed discussion on existing routing protocols can be found in [11-15]. In this review, the characteristics of the routing protocols belonging to unicast, broadcast, multicast, geocast and hierarchical categories are discussed and the suitability of the protocols for the different VANET application scenarios is analysed. Emphasis is given on the adaptive and context-aware routing protocols. The discussions are summarised in Tables I to V.

4. UNICAST ROUTING PROTOCOLS

Unicast routing protocols transmit data packets from a single source to a single destination. They are primarily required to support personalised comfort applications and commercial applications such as Internet connectivity and multimedia access. Unicast routing protocols are the most fundamental protocols in ad hoc environment and they form the basis for constructing other types of protocols. Unicast routing protocols are further classified into topology based, position based, cluster based and hybrid protocols [16].

4.1 Topology based Routing Protocols

Topology based protocols utilise the global information about the network topology and the information about the communication links for making routing decisions. These protocols use either proactive or reactive approaches for routing [17]. Proactive approaches maintain the topology information about all the nodes irrespective of the fact that whether they are presently participating in the communication or not. These methods discover network topology information through periodic control packets and operate independent of current communication needs and network conditions. This increases overhead of joining new nodes into the network and consumes the network resources for control messages. Whereas, reactive protocols determine the routing information for a destination on-demand, only when it is needed for current communication. Reactive routing can be classified either as source routing or hop-by-hop routing. In source routing complete route information from source to destination is included in data packets, whereas in hop-by-hop routing only the next hop address and the destination address are provided. Hop-by-hop routing is better in terms of overall packet delivery ratio and end-to-end delay than source routing and hence it is adopted by most of the routing protocols.

Examples of proactive protocols are Fisheye State Routing (FSR) [18], Destination-Sequentialized Distance-Vector (DSDV) [19] and Optimized Link State Routing (OLSR) [20]. These protocols maintain a next hop table, which is exchanged among the neighbours. Reactive protocols such as Ad hoc On Demand distance Vector (AODV) and Dynamic Source Routing (DSR) have been considered efficient for multi-hop wireless ad hoc networks [21, 22]. AODV is a reactive routing protocol, which supports both unicast and multicast routing. It uses a destination sequence number, which makes it different from other on-demand routing protocols. It reduces memory requirements and the route redundancy. AODV responds to the link failure in the network.

In general, topology based protocols do not scale well in the context of VANETs due to the overheads pertaining to the discovery of routes and maintenance of routes in the presence of moving vehicles. In VANET environment the mobility factor is high, which leads to the frequent network partitioning and route disconnection, demanding recomputation of the topology information [23].

4.2 Position based Routing Protocols

In position based protocols, the routing decisions are based on geographic position of the vehicles. This does not require establishment or maintenance of routes, but requires location services to determine the position of the destination. Some of the commonly used location services include Global Position System (GPS), DREAM Location Services (DLS), Reactive Location Services (RLS) and Simple Location Services (SLS). With the advancement of GPS based location services, position based routing protocols are gaining importance. In position based protocols, the packet is sent without any
knowledge of digital map to the one-hop neighbour, which is the closest to the position of the destination. Every node continuously sends beacon packets with their position information and other node identification parameters. Position based protocols are suitable for VANETs since they offer higher delivery ratio than topology based routing protocols in a highly mobile environment [24]. They provide minimum delay in establishing the route and achieve good scalability. However, privacy is compromised since navigation information is disclosed on the network.

A wide range of forwarding mechanisms have been used by position based routing protocols viz. greedy forwarding, trajectory based forwarding, opportunistic forwarding, contention based forwarding and hybrid forwarding. Position based approaches are further classified into non-delay tolerant network and delay tolerant network.

4.2.1 Non-Delay Tolerant Network (Non-DTN)

Non-DTN protocols are also referred as Min-delay protocols and they aim at minimising the delivery time of the packets from source to destination. These protocols are suitable for time critical safety applications, which demand real-time response during data dissemination. The delay time in the transmission is the major concern in the design of Non-DTN protocols and usually the shortest path method is adopted. However, the shortest path may not always ensure faster delivery, especially when the traffic condition is sparse [15]. These protocols are further classified into beacon based, non-beacon based and hybrid routing protocols.

Greedy forwarding is the commonly used technique, where the packet is forwarded to a neighbour which is geographically closer to the destination node. A local maxima problem occurs, if a packet reaches a node which has no neighbours that is closer to the destination. Each routing protocol in this category applies its own recovery strategy to deal with this situation.

Greedy protocols such as Greedy Perimeter Stateless Routing (GSPR) and AODV are the earliest protocols, based on which later improved protocols like GSR, SAR, A-STAR, GPCR, STAR, GyTAR and CAR emerged. Refer [9] for a timeline of these protocols development. GSPR makes greedy forwarding decisions using only information about the immediate neighbours of the routing node in the network. In case of local maxima situation, it recovers using perimeter forwarding technique. It uses a group model for mobility prediction, which considers the mobility of groups of nodes [25].

GSPR works well in highway environment but suffers in city environment. GSPR relies on distributed algorithm for planarising graphs. In the presence of radio obstacles such as high-rise buildings in city environment, these algorithms frequently partition an otherwise connected graph, making the delivery of packets impossible [26]. Enhanced GSPR and GSPR-L improve the performance for GSPR by selecting the next hop neighbour with good link quality and a non-zero life-time [27, 28]. Geographic Source Routing (GSR) addresses the above issues related with GPSR, by combining position based routing with topological knowledge. It uses RLS to get the position information of the destination and uses a city map for a complete knowledge of city topology [29]. Greedy Perimeter Coordinator Routing (GPCR) also takes advantage of the fact that city streets form a natural planner graph. GPCR improves upon GSR by eliminating the use of external street map. The protocol consists of two parts: a restricted greedy forwarding procedure, which forwards the messages to the nodes at junction and a repair strategy, which is based on the topology of real-world streets and junctions. In recovery mode, packets are backtracked in a greedy fashion to a junction node and using right-hand rule, the next road segment is selected to forward the packets [30].

Another position based routing protocol, Anchor based Street and Traffic Aware Routing (A-STAR), is designed specifically for inter-vehicular communication systems in city environment. Unique to A-STAR is the usage of information on city bus routes to identify an anchor path with high connectivity for packet delivery [31]. A-STAR uses a more efficient recovery strategy for local maxima problem. It computes new anchor paths for recovery and also declares the void area causing local maxima problem temporarily unavailable. It provides better performance as compared to GSR and GPCR. Greedy Traffic Aware Routing (GyTAR) aims at efficient use of network bandwidth and aims at achieving reduced end-to-end delay and packet loss. It adopts a new intersection based geographical routing protocol capable of finding robust routes in city environment with multi-lanes. The key features of the protocol are the selection of the junctions and improved greedy forwarding mechanism. It also takes into account information about speed and direction of vehicles [32]. GpsrJ+ is a prediction based protocol for improving the recovery strategy of GPCR [33]. It uses two-hop neighbor beaconing to predict which road segment its neighboring junction node will take. If the prediction indicates that it’s neighboring junction will forward the packet onto a road with a different direction, it forwards to the junction node; otherwise, it bypasses the junction and forwards the packet to its furthest neighboring node. Table 1 compares the various unicast routing protocols discussed above and many other protocols including CAR [34], STBR [35], LOUVRE [36], GRANT [37], PRB-DV [38], DIR [39], ROMSGP [40], AMAR [41], B-MFR [42], EBGR [43], MORA [44], DGRP [45], RDGR [46], GPGR [47], GPUR [48] and RIRP [49].

In trajectory based forwarding, messages are directed towards a destination using predefined trajectories. Spatial Aware Routing (SAR) [50] uses geographic source route and GSR based packet forwarding. SAR uses spatial model to compute weights based on characteristics of interconnections, such as physical length, average vehicle density and average speed. In SAR, the next hop is selected as a neighbor with
the shortest path to the destination along the GSR, using Dijkstra’s algorithm [50]

**Contention Based Forwarding (CBF)** is a greedy position based forwarding algorithm, which does not require proactive transmission of beacon messages. Instead, data packets are broadcast to all the direct neighbors and they decide whether to forward the packet or not. The actual forwarder is selected by a distributed timer based contention process, which allows the most suitable node to forward the packet and to suppress other potential forwarders. It has been shown that CBF outperforms beacon based greedy forwarding in two-dimensional scenarios with random way-point mobility model [51]. The performance advantage of CBF is most apparent in highly mobile scenarios. When node mobility is high, it provides a lower packet forwarding delay. However, it suffers with local maxima problem in city environment.

Topology-assisted Geo-Opportunistic (TO-GO) is an enhanced geo-routing that improves packet delivery ratio by incorporating junction prediction and opportunistic forwarding with a novel set selection algorithms [52]. TO-GO defines a candidate forwarding set which is selected in such way that nodes in the set can hear each other to prevent hidden terminal collisions. Kevin C Lee et al [52] have shown that even through GPSR, GPCR, GpsrJ+ and TO-GO have similar packet delivery ratio in normal condition, TO-GO performs better when the node density is high and when errors are introduced in the channel.

4.2.2 Delay Tolerant Network (DTN)

Delay Tolerant Network is an approach to networking, which addresses the technical issues related to heterogeneous network that lack continuous network connectivity. They are characterized by limitations of latency, bandwidth, error probability and/or path stability [53]. DTN uses carry and forward strategy to overcome frequent disconnection of nodes in the network. When a node cannot contact other nodes it stores the packet information and forwards the same when an opportunity arises.

Vehicle-Assisted Data Delivery (VADD) [54] is based on the idea of carry and forward approach by using predicable vehicle mobility. The most important issue is to select a forwarding path with minimum packet delivery delay using information about traffic pattern and road layout. As compared to GPRS (with buffer), epidemic routing [80] and DSR, VADD offers high delivery ratio. It is suitable for multi-hop data delivery. Geographical Opportunistic Routing (GeOpps) [55] is a novel delay tolerant routing algorithm that exploits the availability of information from the navigation system in order to opportunistically route a data packet to a certain geographic allocation. This enables selection of vehicles that are likely to carry the information closer to the final destination of the packet. The node with minimum arrival time is selected for forwarding packets. The delivery ratio of GeOpps is dependent on the mobility patterns and the road topology but not dependent on density of vehicles.

Adaptive Road Based Routing (ARBR) assumes that every vehicle knows its geographical position and direction through global positioning system (GPS) and it is equipped with digital maps to determine which road segment or intersection [56]. The ARBR protocol uses two mechanisms to increase delivery ratio and reduce delay: 1) Discovery of high quality path for routing between route-requesting-vehicle and packet-forwarding-vehicle along with discovered path. 2) Stability of routes is guaranteed by updating the path in the header of road reply packet by intermediate nodes. MaxProp [57] is used for sparse networks with limited transmission opportunities. It is based on prioritizing both the schedule of packets transmitted to other peers and the schedule of packets to be dropped. It operates in three basic stages viz. neighbor discovery stage, data transfer stage and storage management stage.

Object Pursuing based on Efficient Routing Algorithm (OPERA) works in sparse situations and it is applicable for both moving and fixed destinations [58]. Optimization of decision making at intersections is based on the connectivity and feasibility metrics. By exploiting the related metrics, next road is selected to forward the packet in order to minimize the overall delay. Position based Directional Vehicular Routing (PDVR) makes sure the packets can be sent to the destination in an efficient and stable route. It selects the next-hop from the vehicles travelling in the same direction as the forwarding vehicle based on their angular direction of relative destination. It is shown that PDVR can maintain more stable routes with lower routing control overhead as compared to AODV [59].
5. CLUSTER BASED ROUTING PROTOCOLS

Clustering in vehicular ad hoc network can be defined as the virtual partitioning of the dynamic nodes into various groups. A group of nodes identify themselves to be part of a cluster. A special node, designated as cluster-head is responsible for routing, relaying of inter-cluster traffic, scheduling of intra-cluster traffic and channel assignment for cluster members. The cluster members do not participate in routing. An optional gateway node is also used in some of the clustering schemes, which belongs to more than one cluster, acting as a bridge between cluster heads. Inter-cluster communication is achieved either by cluster-heads or gateways, if present, whereas communication within each cluster is made through direct link. As the complexity and mobility of the network increases, the selection of cluster heads and the management of clusters becomes a
6. HYBRID PROTOCOLS

Hybrid routing protocols combine the advantages of both proactive and reactive approaches. In hybrid protocols, the network is divided into two levels. The inner layer is proactive, which maintains and updates information on routing between all nodes of a given network at all times. Route updates are periodically performed regardless of network load, bandwidth constraints, and network size. Inner layer comprises easy-to-maintain routes, while a routing table is maintained, whereas the outer layer is reactive, the route is determined on need basis. Thus, if a node wishes to initiate communication with another host to which it has no route, a global-search procedure is employed.

GeoDTN+Nav [69] combines DTN and Non-DTN mode, which includes a greedy mode, a perimeter mode and a DTN mode. It switches from non-DTN mode to DTN mode by estimating the connectivity of the network based on the number of hops a packet has travelled so far, neighbor’s delivery quality, and direction of neighbor with respect to the destination. The delivery quality of neighbors is obtained through virtual navigation interface, which provides necessary information for GeoDTN+Nav to determine its routing node and forwarding node. In sparse network, the latency increases and the packet delivery ratio drops at which point GeoDTN+Nav tries to fall back to DTN mode again.

7. BROADCAST ROUTING PROTOCOLS

This is the most frequently used routing protocol in VANETs, especially in safety related applications. In broadcast mode, a packet is sent to all (even unknown or unspecified) nodes in the network and in turn each node re-broadcasts the message to other nodes in the network. Flooding is a prominent technique used in broadcast routing protocols. However, blind flooding results in broadcast storm problem. A broadcast storm can overload

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the limited channel capacity, causing channel congestion that reduces communication reliability. Broadcast protocol is suitable only for small number of nodes in the network. As the density of nodes increases, there is an exponential increase in message transmission, which results in higher bandwidth consumption. The broadcast routing protocols are classified into traffic based, area based, cluster based and probability based routing protocols. Refer Table 2 for comparison of various broadcast routing protocols.

7.1 Traffic based Broadcast Routing Protocols

In traffic based broadcast routing algorithm, a source node broadcasts a packet to all its neighbours and each of those neighbours, in turn, re-broadcast the packet exactly one time. This process continues until all the reachable network nodes have received the packet. The Distributed Vehicular broadcast protocol (DV-CAST) [70] uses local one-hop neighbor topology to make routing decisions. The protocol adjusts the back-off timer based on the local traffic density, and computes connectivity in forward and opposite direction with periodic heartbeat messages. This protocol divides the driving environment into three types of regions depending on the local connectivity as well-connected, sparsely connected and totally disconnected neighborhood. In well-connected network, it applies any one of the broadcast suppression schemes using probability: weighted p-persistence or slotted 1-persistence or p-persistence [70]. In sparsely connected neighborhood after receiving the broadcast message, vehicles immediately rebroadcast it to vehicles moving in the same direction. In totally disconnected neighbourhood vehicles are used to store the message until another vehicle enters into transmission range, otherwise if the time expires it will discard the packet. DV-CAST addresses how to deal with extreme situations such as dense traffic conditions during rush hours and sparse traffic during certain hours of the day. However, this protocol is attributed with high overhead and end-to-end delay during data transfer.

7.2 Area based Broadcast Routing Protocols

Area based routing protocols use the concept of coverage area to adjust the rebroadcast region within the specified geographical area. In this scheme, every vehicle receives multiple packets which may contain overlapping information. Scrutinizing these messages provides additional coverage area. The node that is farther away from the source is preferred for re-broadcast to widen the coverage area.

7.2.1 Distance and Hop based Routing Protocols

In distance and hop based methods, messages are broadcast by considering the neighbouring distances and hop count from the transmitting node. The distance between the source and destination is the criteria for deciding whether to re-broadcast to destination or drop the message. Fast Broadcast (FB), a distance based routing protocol, minimizes forwarding hops during transmission of messages. It works in two phases viz. estimation phase, in which the transmission range is adjusted using heartbeat messages to detect backward nodes and broadcast phase, in which the message is transmitted by assigning higher priority to the vehicles that are farther away from the source node. Cut-Through Rebroadcasting (CTR) gives higher priority to rebroadcast alarm messages to farther vehicles within the transmission range but operates in a multi-channel environment [71]. Optimized Dissemination of Alarm Message (ODAM) has a defer time to broadcast messages, which is computed based on the distance between source node and receiver node. Broadcast of messages can only occur within risk zone area, determined with a dynamic multicast group based on vehicles proximity to the accident site [72].

Distributed Fair Transmit Power Assignment for Vehicular Ad hoc Network (D-FPAV) describes a scheme that provides fairness in broadcasting heartbeat messages by dynamically adjusting transmission power of each node based on distance to other neighbouring nodes [73]. Although power control is a well explored research topic for wireless networks, D-FPAV investigates the problem in the context of broadcasting in vehicular networks using realistic vehicle movement traces. Rex Chen et al [74] also propose a mechanism to dynamically control the communication range by adjusting the transmission power to mitigate the effects of broadcast storm. They discuss multi-hop broadcasting especially in a shockwave scenario which separates the traffic into two streams with different densities and speed. When the first vehicle of the following stream meets the last vehicle of the leading stream, it senses the danger and immediately sends a broadcast message to all nearby vehicles to caution to reduce the speed.

7.2.2 Location Based Routing Protocols

In location based methods, messages are broadcast based on the geographic area of the vehicles. Each node adds its own location in the header of the message, which is used by the receiving node to calculate the additional coverage area to re-broadcast. The main problem with this approach is the cost of calculating additional coverage areas. Location Based Broadcast (LBB) [75] protocol is designed to meet the communication requirements of highway safety applications. In Location Based Broadcast, sender broadcasts messages to all receivers in its communication range. It is the receiver's responsibility to determine the relevance of message and provide proper response. The decision is made based on the relative position of the sender (in front, behind, left lane etc.), the purpose of the message (brake warning, lane change warning, accident reporting, congestion prediction, etc.) and the highway traffic condition. Urban Multi-Hop Broadcast Protocol (UMB) [76] and Ad hoc Multi-hop Broadcast (AMB) [77] are designed especially for multi-hop broadcast in urban scenarios addressing broadcast storm problem, hidden node problem and reliability issues. Each node during broadcasting, selects the farthest node to forward the message. UMB protocol efficiently broadcasts packets.
with high delivery ratio using repeaters installed at junctions. Whereas, AMB protocol solves the infrastructure dependence of the UMB Protocol. It is extension of the UMB protocol composed of two parts, namely directional broadcast and intersection broadcast.

Multi-Hop Vehicular Broadcast (MHVB) [78] is a flooding algorithm, which assumes availability of GPS device for position information. It implements congestion suppression algorithm and adopts backfire algorithm to select the farthest forwarding node to relay the message efficiently. In enhanced MHVB, angle is added as a parameter to the backfire algorithm. V-TRADE/HVTRADE [79] organises nodes into groups, where only a small subset of vehicles is selected to re-broadcast the message. These protocols show considerable improvement in performance, but they incur a routing overhead in selecting nodes to do the re-broadcasting.

Epidemic routing is introduced as an alternative approach for partially connected ad hoc networks. It exchanges random pair-wise messages among mobile nodes. The epidemic algorithm is flooding based, and it trades system bandwidth and node buffer space for the eventual delivery of a message [80]. It does not rely on end-to-end connectivity. Border node Based Routing (BBR) protocol is designed for partially connected network that has some of the attributes of epidemic protocol, but offers performance comparable to more conventional protocols under fully-connected network conditions. BBR protocol is designed for sending messages either in unicast mode or in broadcast mode [81].

Relative Position Based Message Dissemination (RPB-MD) [82] adopts relative position based addressing model and directional greedy broadcasting routing to forward messages without requiring external location services. RPB-MD achieves high delivery ratio, limited overhead and reasonable delay at different vehicle densities. Beacon-less Routing Algorithm for VANET Environment (BRAVE) [83] is a novel beacon-less protocol, which is designed based on the idea of spatial awareness and beacon-less geographic forwarding. It is specifically designed to address the issues related to (i) selection of next hops, which will lead to successful transmission (ii) forwarding inefficiencies including cycles associated with the beacon messages (iii) failure of message delivery due to disconnected topologies and (iv) data packet reaching local optimum in trajectory based routing schemes. BRAVE performs hop-by-hop data forwarding along a selected street using opportunistic next hop selection method. It uses a reactive scheme for the selection of the next forwarder from those neighbours who have successfully received the message instead of using period beacon messages. In addition, this protocol works in a opportunistic store-carry-and-forward paradigm to cope with uneven network densities and disconnected topologies. BRAVE is fully localized protocol requiring information only from neighbours, which guarantees scalability with respect to the number of vehicles in the network. Da Li et al [84] propose a distance based broadcast protocol called Efficient Directional Broadcast (EDB) which is composed of two parts viz. directional broadcast on the road and directional broadcast at the intersection. At the intersection, a directional repeater is installed which is used to forward the message to vehicles on the different road segments incident to the intersection of different directions. It has many advantages including long transmission range, space reuse, low redundancy and collisions.

7.3 Cluster based Routing Protocols for Broadcast

We have discussed cluster based protocols for unicast routing in Section IV. Here we consider the cluster based protocols, which broadcast messages to a group of vehicles, for example, to a fleet of vehicles with common paths. The Mobility-centric Data Dissemination algorithm for Vehicular networks (MDDV) [85] combines the idea of

Table 3: Comparison of Multicast/Geocast Routing Protocols

<table>
<thead>
<tr>
<th>Routing Protocols</th>
<th>Forwarding Strategies</th>
<th>Recovery Strategies</th>
<th>Scenario</th>
<th>Mobility models</th>
<th>Propagation models</th>
<th>OOS Parameters</th>
<th>Digital Map</th>
<th>QOS</th>
<th>Delay</th>
<th>Delivery PDR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Traffic based</td>
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<tr>
<td>BBR</td>
<td>X</td>
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<tr>
<td>ROVER</td>
<td>X</td>
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<tr>
<td>Distance &amp; hop based</td>
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<tr>
<td>GvGrid</td>
<td>X</td>
<td>X</td>
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<td>IVG</td>
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<td>DRG</td>
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<td>DTSG</td>
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<td>VCARP</td>
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</table>

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opportunistic forwarding, trajectory based forwarding and geographical forwarding. Edge-Aware Epidemic Protocol (EAEP) [86] is a reliable, highly dynamic protocol, which aims to improve bandwidth efficiency. It reduces control packet overhead by eliminating exchange of additional hello packets for message transfer between different clusters and simplifies cluster maintenance. Each vehicle piggybacks its own geographical position to the broadcast messages, which eliminates beacon messages. Upon receiving a new re-broadcast message, EAEP uses transmission count from front nodes and back nodes in a given period of time to calculate the probability for making decision whether nodes will re-broadcast the message or not.

7.4 Probability based Routing protocols
Among the various broadcast techniques to overcome the problem of flooding, probability based approach is becoming attractive. When there are more contenders to broadcast, a predetermined probability is assigned to each node which reduces the chances of collision and re-broadcasting. These algorithms adopt different schemes such as p-persistence, slotted 1-persistence and weighted p-persistence. In weighted-p-persistence, the fundamental idea is the usage of probability, instead of delay timer; upon receiving a message each node will retransmit it with a probability ‘P’. This solves the issues of redundant re-broadcasting, congestion and collision. Probability based approaches are simple to implement and does not create any overhead but has the risk of missing some messages. The performance of the algorithm drastically depends on the selection of value for ‘P’ [70].

In Receipt Estimation Alarm Routing (REAR) [87] protocol, nodes are selected to relay broadcast messages based on their estimated message received value. It is computed based on the received signal strength and packet loss rates. This information is exchanged with the neighbouring nodes using heartbeat messages. Hence, nodes with higher delivery ratios are likely candidates to flood messages in the network. It works on the Manhattan mobility model for urban areas and a highway scenario with bi-directional single lane traffic. Other probability based routing protocols include Position-based Adaptive Broadcast (ABS) [88].

8. MULTICAST/GEOCAST ROUTING PROTOCOLS
Multicast routing enables dissemination of messages from single source to a group of destination nodes of interest. Geocast routing is basically a location based multicast routing, which aims to deliver information from a source node to all other nodes within a specified geographical region called a Zone of Relevance (ZOR). A Zone of Forwarding (ZOF) is defined within which the packets are directed instead of simply flooding the packets everywhere in the network. This reduces the overhead and network congestion. This protocol is applicable for safety and convenience related applications. The various Multicast/Geocast routing protocols are described in the following sections. Refer Table 3 for comparison of Multicast/Geocast routing protocols.

8.1 Topology based Approaches
Topology based approaches select forwarding nodes based on the network topology information, which can be either multicast tree or multicast mesh. A multicast group is not constrained by a particular location; a group of members can be defined by unique and logical group identification such as class-D IP address.

Robust Vehicular Routing (ROVER) [89] is a reliable geographical multicast protocol, where only control packets are broadcasted in the network and the data packets are unicasted. The objective of the protocol is to send a message to all other vehicles within a specified ZOR. When a vehicle receives a message, it accepts the message if it is within the ZOR. It also defines a ZOF, which includes the source and the ZOR. All vehicles in the ZOF are used in the routing process. It uses a reactive route discovery process within a ZOR. This protocol creates lot of redundant messages in the network, which leads to congestion and delay in data transfer.

8.2 Location based Approaches
Location based approaches select forwarding nodes based on location information such as the position of sending/receiving nodes, the position of neighbouring nodes, and the coordinates of a multicast region. Since forwarding

Table 4: Comparison of Hierarchical Routing Protocols

<table>
<thead>
<tr>
<th>Routing Protocols</th>
<th>Forwarding Strategies</th>
<th>Recovery Strategies</th>
<th>Scenario</th>
<th>Mobility models</th>
<th>Propagation models</th>
<th>Digital map</th>
<th>CAOS Parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td>DPP</td>
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<tr>
<td>CTP</td>
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<tr>
<td>BROADCOM M</td>
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<tr>
<td>HCB</td>
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</tbody>
</table>

http://www.cisjournal.org
nodes are selected during dissemination of each multicast packet, there is no need to maintain multicast trees and hence less overhead. These protocols are further divided into two schemes: approaches with location-independent and approaches with location-dependent. Inter-Vehicles Geocast protocol (IVG) [90] is developed for disseminating safety messages to vehicles on highways. The multicast group is defined dynamically using vehicles within the risk area, which is determined by the driving direction and position of vehicles. This group is defined temporarily and dynamically by the location, speed, and driving direction of vehicles. This protocol uses a timer based mechanism for forwarding messages and periodic broadcasts are used to overcome network fragmentation for delivering messages to the multicast members. The rebroadcast period is calculated based on the maximum speed of vehicles. Besides, IVG protocol reduces the number of hops by using the deferring time. A vehicle, which is farthest from the source node, has less deferring time to rebroadcast.

GvGrid [91], a QoS routing protocol for VANETs is an on-demand, position based protocol. GVGrid partitions maps into equal-sized grid squares where a node selects the next hop node from its neighbouring grids. It uses neighbor selection algorithm and route selection algorithm to select a route consisting of vehicles which are likely to move at similar speeds and in similar direction. GvGrid implements an efficient route recovery algorithm which does not construct a new route altogether but identify the new nodes that complement the missing nodes and recovers a high quality route quickly. GvGrid provides longer lifetime for route and improved packet delivery ratio as compared to GPCR [91]. Distributed Robust Geocast (DRG) [92] routing protocol improves the reliability of message forwarding by defining the ZOF, which surrounds the region of interest (ROI). Vehicles in the ZOF region forward the message to other vehicles in the ROI. It uses distance based back-off mechanism for directed and restricted flooding and overcomes network fragmentation problem by scheduled retransmission. Geographical based routing protocols such as Greedy-Face-Greedy (GFG) and Greedy Other Adaptive Face Routing (GOAFR) also have been developed to provide scalable communication in VANETs.

The main aim of Dynamic Time-Stable Geocast Routing (DTSG) [93] is to maintain the availability of the messages for a certain period of time within the area of interest. Time stable geocast protocol finds place in commercial applications in addition to accident emergency warning applications. It works in two phase viz. pre-stable period and stable period. DTSG protocol guarantees delivery of message to the intended vehicles entering the region for a certain amount of time and it works well even in sparse networks. The performance of this protocol is independent of the density of vehicles, speed of vehicles, and the broadcasting range, which makes it more robust.

9. HIERARCHICAL ROUTING PROTOCOLS

Clustering permits large networks to be managed efficiently as hierarchical structures. Partitioning nodes into clusters forms a single hierarchy, whereas, in a multilevel hierarchical routing, nodes are organised into a tree-like structure with multiple levels of clusters [94]. Overlapping clusters is often a desirable feature, which can significantly reduce the number and duration of interruptions in communication when the network gets partitioned due to moving nodes. However, one should be cautious of hidden terminal problem in the overlapping region. The efficiency of distributed clustering schemes depends on the number of clusters formed and the goal is to reduce the number. In hierarchical routing, paths are recorded between clusters instead of between individual nodes due to which the stability of the route is increased. Hierarchical clustering provides scalability for large networks, and stability for dynamic networks. It is an attractive approach to address broadcast storm problem as well. The various Hierarchical based routing protocols are described in the following sections. Refer Table 4 for comparison of hierarchical based routing protocol.

Directional Propagation Protocol (DPP) [95] proposes clustering scheme where cluster formation is based on the mobility factor, including the direction of moving vehicles for information propagation. DPP consists of three components: Custody Transfer Protocol, Inter-Cluster Routing Protocol and Intra-Cluster routing protocol. The Custody Transfer Protocol is responsible for buffering the messages until they are received by the next-hop cluster. The inter-cluster and intra-cluster routing protocols, as the names suggest, take care of the communication within and between the clusters respectively. DPP is a distributed algorithm which works irrespective of the traffic density.

The BROADCOMM [96] protocol uses a two level hierarchical structure for highway networks. The first level...
WiMax or HSPA for long range communication. Layer-1 comprises simple nodes and one or two super nodes. Relaying (TAPR) protocol uses an adaptive mechanism, changing network topology. Traffic Adaptive Packet Relaying (TAPR) protocol uses an adaptive mechanism, which decides whether to route through co-directional or oncoming clusters. Cenerario et al [100] propose a novel scheme of conditional dissemination of information, which is based on the encounter probability of an event. The information dissemination area, direction, distance and the useful time periods are calculated adaptively based on the encounter probability. A context-aware multicast routing protocol for emergency warning messages has been proposed by Alvin Sebastian et al [101]. This protocol has been developed based on minimum delay multicast tree combined with contention based relaying. It uses a context-aware strategy, which identifies the endangered vehicles and is able to deliver the warning messages efficiently in various road traffic scenarios [101].

10. ADAPTIVE/CONTEXT-AWARE ROUTING PROTOCOLS

The network topology in VANET scenario by itself is an emerging phenomena based on the interactions of the vehicles. An adaptive approach is essential to deal with the current network conditions and to cope with the problems of network distortions due to radio signal interference and node movements. Adaptive routing algorithms, in general follow two approaches viz. context-aware protocols and swarm intelligence based protocols. Table 5 compares the various Adaptive/Context-Aware routing protocols.

Context-aware protocols are knowledgeable about the situation of their physical and virtual environment and they can respond in some way to benefit from that knowledge. A context can be defined as any information that can be used to characterise the situation of an entity [98]. A context in vehicular ad hoc environment includes road traffic and communication network situation perceived by the vehicle. Adaptive Connectivity Aware Routing (ACAR) protocol [99] selects an optimum route adaptively based on the quality of the network transmission, which is determined by the statistical and real-time density data gathered on-the-fly. This protocol is suitable for large networks with rapidly changing network topology. Traffic Adaptive Packet Relaying (TAPR) protocol uses an adaptive mechanism, which decides whether to route through co-directional or a virtual cell of nodes and second level is a collection of cell reflectors, which are few nodes that are located close to the geographical centre of the cell. The cell reflectors act as cluster heads and handle the emergency messages from the members of the cell or from the neighbouring cells. Hierarchical Cluster Based Routing (HCB) [97] is a novel protocol designed with two-layer communication architecture and suitable for highly mobile ad hoc networks. In this protocol two types of nodes are present; one with single WiFi interface and they communicate via multi-hop path and another one is called super node with WiMax or HSPA for long range communication. Layer-1 comprises simple nodes and one or two super nodes whereas layer-2 consists of only super nodes.

### Table 5: Comparison of Adaptive/Context-aware Routing Protocols

<table>
<thead>
<tr>
<th>Routing Protocols</th>
<th>Forwarding Strategies</th>
<th>Coordinating Strategies</th>
<th>Recovery Strategies</th>
<th>Scenarios</th>
<th>Mobility models</th>
<th>Propagation models</th>
<th>Digital map</th>
<th>QoS Parameters</th>
<th>Delay</th>
<th>Delivery</th>
<th>Performance</th>
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</thead>
<tbody>
<tr>
<td>AntNet</td>
<td>√</td>
<td>√</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>Normal</td>
</tr>
<tr>
<td>ABC</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
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<td>N</td>
<td>N</td>
<td>Normal</td>
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<tr>
<td>TAPR</td>
<td>N</td>
<td>N</td>
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<td>N</td>
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<td>N</td>
<td>Normal</td>
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<tr>
<td>ACAR</td>
<td>√</td>
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<td>Normal</td>
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<tr>
<td>Position based</td>
<td>ACO</td>
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<td>√</td>
<td>√</td>
<td>√</td>
<td>Normal</td>
</tr>
</tbody>
</table>

The main concept of swarm intelligence is the collective intelligence; a large number of participating agents, which are individually not intelligent but through emerging behaviour they achieve much bigger task collectively, which is beyond the capabilities of individual agents. They perform highly complex tasks of global optimization using only local information without a centralised coordination. Ant Colony Optimization (ACO) is another well-known bio-inspired technique designed to solve hard combinatorial optimization problems. Among the different multi-agent coordination mechanisms, the most popular is the use of stigmergy [102]. For the development of adaptive routing protocols, two mechanisms related to stigmergy are of most importance: the way the pheromones are deposited in the paths of the ants and the way these evaporate within the passage of time [103]. Successful implementations of swarm intelligence include AntNet [104] and Ant Based Control (ABC) [105]. AntNet uses two types of ants: forward ants and backward ants. Forward ant explores network to find path to destination and backward ant re-enforces the path from destination to source. The routing table is updated using the trip times of the backward ants. In ABC algorithm, the routing table is updated based on the life of the ant, which is the sum of the delay of the nodes. These algorithms exhibit robustness under various network conditions but lack scalability. For large networks, the amount of traffic generated is huge, since each node has to send an ant to all nodes of the network. For longer distances, there is a chance of losing ants and for large travelling times ant’s path is out dated by evaporating...
pheromone substance. Adaptive Swarm based Distributed Routing (A-SDR) addresses the problem of scalability by clustering the nodes into colonies. It uses a local ant to discover routes within the colony and a colony ant to discover routes across colonies. It also addresses full utilization of the network capacity, routing oscillations and routing loops [106].

11. SIMULATION RESULTS

We have simulated and studied the performance of broadcast and unicast routing protocols for VANETs using Network Simulator (NS-2) [107]. We have considered the simulation area of 1500mx1500m, with bidirectional road scenario. The simulation study focused on packet delivery ratio, latency and overhead. The simulation parameters for the network scenario are described in Table 6.

Table 6: Simulation Parameters

<table>
<thead>
<tr>
<th>Sl. no.</th>
<th>Parameters</th>
<th>Specifications</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>Network Simulator</td>
<td>NS-2, Version 2.29 and Version 2.34</td>
</tr>
<tr>
<td>2</td>
<td>Simulation Time</td>
<td>800 Seconds</td>
</tr>
<tr>
<td>3</td>
<td>Number of nodes</td>
<td>20, 40, 60, 80 and 100</td>
</tr>
<tr>
<td>4</td>
<td>Speed</td>
<td>20km, 60km, 80km</td>
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<tr>
<td>5</td>
<td>Data Type</td>
<td>Constant Bit Rate (CBR)</td>
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<td>6</td>
<td>Source/Destination</td>
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<td>7</td>
<td>Data packet size</td>
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<td>8</td>
<td>MAC Protocol</td>
<td>IEEE 802.11</td>
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<tr>
<td>9</td>
<td>Propagation Model</td>
<td>Two-ray ground model, Road blocking</td>
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<td>10</td>
<td>Mobility Model</td>
<td>Random Way Point (RWP), Multi-agent Traffic Simulator (MTS)</td>
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<tr>
<td>11</td>
<td>Channel Type</td>
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</tr>
<tr>
<td>12</td>
<td>Antenna Model</td>
<td>Omni directional, directional</td>
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</tbody>
</table>

11.1 Simulation of Broadcast Routing Protocols

The broadcast routing protocols considered for our simulations are DV-CAST, LBB and AMB. DV-CAST is traffic based protocol, whereas LBB and AMB are Location-based protocols. In simulations, DV-CAST routing protocols are included in the base code of the broadcast routing protocol and we have added the persistence values during rebroadcasting. Figure 2.a shows the average packet delivery ratio versus density of nodes. Among these protocols, AMB offers higher packet delivery ratio. The performance of AMB is consistent even when the density of vehicles increases, because it uses an effective mechanism for forwarding the broadcast packet; it chooses only one node, which is closest to the intersection for forwarding. LBB protocol is based on the repetition coding, one message is sent ‘n’ times with an idea of enhancing the probability of packet delivery. However, as the density of the vehicle increases, excessive repetitions occur, which results in degradation of the performance as seen in figure 2.a. It is obvious from Fig 2.a that the performance of the traffic based DV-CAST protocol is inferior compared to the location based protocols. However, by appropriately selecting the probability values such as 0.5, tries to improve the performance during the re-broadcasting and DV-CAST (0.5 persistence) offers packet delivery ratio comparable to LBB.
Figure 2.b. shows the latency of the broadcast routing protocols over number of vehicles. Location based protocols (AMB and LBB) has less delay compared to the traffic based protocols (DV-CAST). It may be noted even though the packet delivery ratio of AMB is consistent with respect to vehicle density; the delay slightly increases when the number of vehicles is increased. This is due to the fact that the number of vehicles is increased. This is due to the fact that the number of candidate intersection vehicles is increasing when the vehicle density increases which causes collision of RTB packets.

11.2 Simulation of Unicast Routing Protocols

We have considered the routing protocols GPSR and GCPR, which are position based protocols using GPS and AODV and DSR, which are topology based protocols. Figure 3.a exhibits the packet delivery ratio versus distance in meters. It is quite evident from the graph that both position based protocols such as GPSR and GCPR are performing much better than topology based protocols. In topology based protocols, the packet delivery ratio drops drastically as the distance increases. This is due to the fact that overhead packets for route discovery in topology based protocols. Among the position based protocols GCPR performs better as compared to GPSR.

Figure 3.b and Figure 3.c depict the average latency versus the distance and average overhead versus distance respectively. From these results, it is clear that position based protocols (GPSR and GCPR) possesses low latency and overhead as compared to the topology based protocols (AODV and DSR). This is due to the fact that these position based protocols use GPS based location services, which do not have the overhead of re-establishing the path when it is disturbed due to high mobility of nodes.

12. DISCUSSION AND CONCLUSION

Design of efficient routing protocols for VANET is one of the major challenges to be addressed in order to leverage the benefits of the VANET technology to day-to-day life. Performance of routing protocol for VANETs depends drastically on the mobility of nodes, vehicular density and several external factors such as driving environment. It also depends on the use of appropriate mobility model and propagation model. The protocol should perform well in both dense and sparse traffic conditions either in city or highways seamlessly. A universal routing solution for all VANETs application scenarios may not be viable; we need to design specific routing protocol and mobility model to fulfill the specific QoS requirements of each application.

Safety related applications are hard real-time in nature and demand very low latency and guaranteed delivery of packets. Both unicast and broadcast protocols find place in safety related applications. Even though flooding is a technique suitable for such applications, blind flooding leads to broadcast-storm problem and results in fragmentation in network. An intelligent and optimised broadcast protocol is required to alleviate these issues. Even though convenience and comfort applications demand low latency, effective use of available bandwidth and ensuring better packet delivery ratio are of paramount importance. These applications also demand that the routing protocol should scale well with the increase in the number of users/vehicles and should adapt to different environment/traffic scenarios seamlessly. Multicast and Geocast protocols are preferred over flooding techniques in order to ensure end-to-end quality of service. Automated highways applications demand the intelligent use of information disseminated to make safe and appropriate decisions in real time in any traffic situation for autonomous driving.

Proactive approaches for routing have the overhead of maintaining the routing table containing the information of all the nodes in the network and sharing it among the nodes, which reduces the usable bandwidth. On the contrary, reactive approaches discover the routes between the nodes that are communicating on-demand and hence less overhead of route maintenance. It is obvious that topology based protocols do not scale well for VANET environment. With the proliferation of GPS based services, position based protocols are becoming popular. In addition, position based methods do not have the overhead of establishing and maintaining routes. Most commonly used forwarding strategies by position based protocols include greedy forwarding and trajectory based forwarding. Position based routing methods suffer from finding the exact localization of the vehicles due to the inherent inaccuracy of the GPS location. Delay tolerant network technique uses the store and forward method. This guarantees the delivery of data but suffers from large delay, which makes them not suitable for emergency related applications.

Cluster based routing protocols are suitable for regional services and extend the different services by means of inter-cluster and intra-cluster communication. However, they pose challenges in maintaining dynamically varying clusters and dynamic selection of cluster head. Multilevel clusters enable hierarchical routing, which improves scalability and stability of paths. Adaptive routing in general follow two approaches namely methods based on context-awareness and methods inspired by natural phenomenon such as ant behaviour. Context-aware routing protocols try to incorporate external sources of information such as digital maps, positioning systems, location services or even schedules of public transport to improve the performance. Swarm intelligence based protocols aim to build self-organizing networks based on the collective intelligence of groups of simple agents, i.e. network nodes.

In this paper, we reviewed a large number of routing protocols that are available in the literature and categorized them concisely in the form of a taxonomy based on key attributes. The salient characteristics of these protocols are also summarised in Table 1 to 5. Simulation of broadcast and unicast routing protocols
using topology and position based techniques is carried out using NS2 simulator and the results are discussed. This survey is part of the research work, which aims to develop a generic architecture for ITS to support safety, convenience and comfort applications using layered multi-agent approach [108]. This involves design and integration of different routing protocols meeting the quality of service requirements of the applications in each layer.

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