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State of the Art VANETs Routing Protocols: A Literature Review

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Abstract
Wireless technology, especially Vehicular Ad-hoc Network (VANET), is developing rapidly. VANET is an emerging technology that assists intelligent transportation systems by improving traffic services and helping in minimizing road accidents. Data sharing in VANETs is time-critical, necessitating the formation of fast and robust network connections. Due to the highly dynamic nature of VANET, providing reliable, consistent, and seamless communication is a significant challenge. In the last decade, various routing approaches have been proposed to efficiently handle quick handover of safety and infotainment-related VANET applications. This paper reviews and investigates the existing routing protocols and classifies them into a taxonomy based on essential attributes such as forwarding strategies, routing strategies, network dimensions. Routing challenges and future research directions in the VANET area are discussed in this paper.

Keywords- Intelligent transportation systems, VANETs, Routing Protocols, IEEE 802.11p, Vehicle routing.

1. Introduction

People's continuous mobility, the growing number of vehicular traffic, and the requirement for infrastructure-free wireless communication for intelligent transportation systems (ITS) contribute to the importance of VANETs as a research topic in vehicular and wireless technologies. VANET is a Mobile Ad-hoc Network (MANET) extension that allows for pleasant and safe travel. VANET makes use of the IEEE 802.11p standard to disseminate information within vehicles and nearby fixed infrastructure consisting of roadside units (RSU). RSU acts like a gateway for connecting to some server or internet for getting application-based services. Vehicles communicate position, speed, and acceleration data by using GPS sensors installed on the vehicle's roof. VANET uses vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I), and infrastructure-to-infrastructure (I2I) communication models, as represented in Figure 1. VANET inherits some properties from MANET like mobile nodes and self-organizing nature but possesses unique features like high node mobility, frequent link breakages, dynamically topology changes, and time-varying node density. Constructing a network between running vehicles and ensuring reliability and security in roaming is a significant research challenge in VANET (Mekki et al., 2017). Many studies have been carried out in recent times on various aspects of VANET, including medium-access-layer (MAC) improvements (Shah et al., 2019), reliability and latency improvements (Abbas et al., 2018), security and privacy plans (Schoch et al., 2006), VANET-LTE integration (Sivaraj et al., 2011), and designing advanced routing protocols aiming to offer decent throughputs and resilience for dynamic topologies.

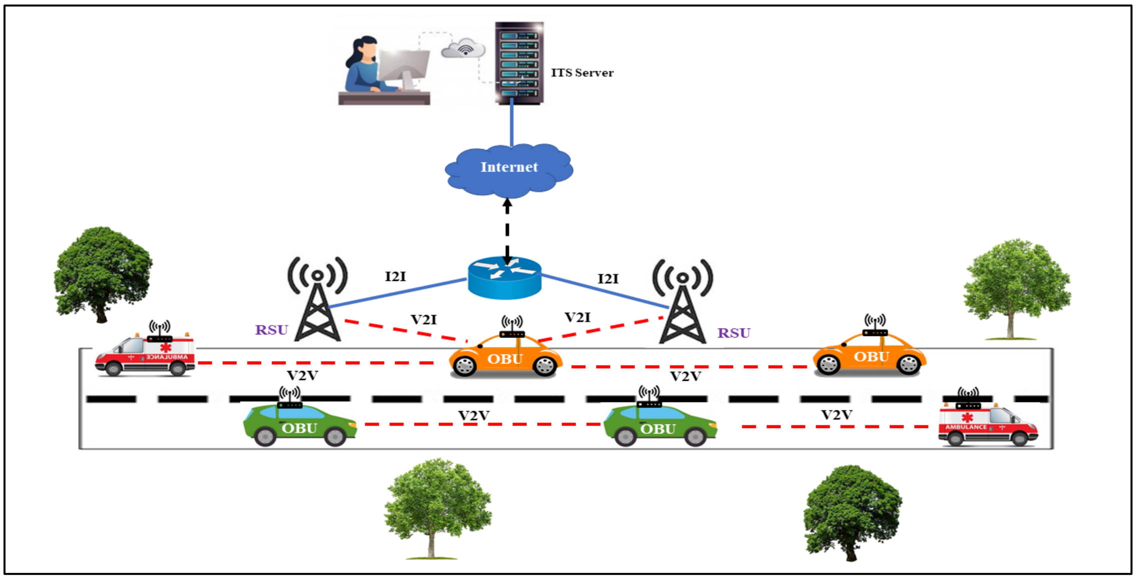

Figure 1. VANET communication model.

Routing in VANET is critical because it is responsible for establishing and maintaining routes for multi-hop communication. High node mobility and regular topology changes contribute to high connectivity overhead for exchanging and updating topology information. Numerous types of obstacles of different shapes and dimensions and variations in node density add to the difficulty of improving the routing protocol work. Some of the significant challenges in VANET routing are discussed as follows:

- **Large scale and highly dynamic network:** VANETs are formed by running vehicles like cars, buses, ambulances, etc., at an average speed of 60 km/h. Due to the high speed of vehicles, the topology of a network changes very frequently, causing communication link breakage. Vehicles inside the communication range exit within fractions of seconds, causing network disconnections. Vehicles rapidly enter and exit the networks that trigger unpredictable path availability changes between sources and targeted vehicles. Therefore, designing a routing protocol is more challenging for VANETs applications.

- **Predicted mobility:** Nodes in MANET follow random mobility, whereas VANETs node mobility is restricted by the road topology, traffic signals, and speed limit. So, the node's mobility mobile must be selected carefully to simulate the real road traffic.
- **Radio channel constraints:** The obstacles between two communicating vehicles like buildings, trees, and traffic signs prevent the signal from reaching its destination. It increases the fading in the communicated signal. Even though vehicles themselves cause reflection, refraction, and scattering in radio signals. Channel congestion can also occur in VANET because it does not have a central coordinator to manage the overall channel bandwidth (Al-Sultan et al., 2014).
- **Hard delay constraints:** Most VANET Health monitoring applications have hard delay constraints. VANET based health monitoring applications use V2V and V2I communication to improve road safety and avoid accidents. Warning and safety messages must be transmitted and arrived at a specific time to avoid car accidents, save people's lives, and maintain a clean environment. However, the absence of a central coordinator causes bandwidth mismanagement that increases the latency for disseminating messages.
- **Security and Privacy issues:** Security and privacy issues are the most significant barriers because medical data is susceptible. Attackers may eavesdrop on the message, obtain sensitive data and blackmail the people. Security and privacy breaches can cause severe legitimate and monetary consequences (Srinivas et al., 2019).

Continuous research is being conducted to enhance routing decisions while considering the constraints mentioned above and the challenges in VANETs (Singh et al., 2021). VANET routing protocols are classified as V2I or V2V based on whether or not vehicles employ RSUs to transmit packets to their final destination. V2V data communication is considered the most effective strategy for emergency and multimedia message distribution. This paper reviews and investigates the existing routing protocols and classifies them into a taxonomy based on essential attributes such as forwarding strategies, routing strategies, network dimensions. The remainder of this work is structured as follows: The comprehensive literature-review approach utilized in this survey is described in Section 2. Section 3 covers the summary and describes the findings, and Section 4 concludes the paper.

2. VANET Routing Protocols

Routing protocols are in charge of gathering the information required to build and maintain routes between nodes. Routing algorithms identify which of several paths between source and destination is the best one. Routing is critical in delivering traffic and other important notifications to their intended recipients. The more efficient routing better the performance in VANET (Yaqoob et al., 2017). Various MANETs routing protocols were applied in the VANETs context in previous studies Nair (2016), Brendha et al. (2017), Patel et al. (2015), but they are not directly applicable because of their unique features. Any routing protocols performance in VANET depends on various internal and external factors like vehicles speed, frequent network partitioning, link breakages, road trajectories, traffic densities, and roadside objects such as buildings and trees. VANET has predictable topologies with movement direction and speed as vehicles move alongside the road networks. So, selecting an appropriate mobility model could improve routing algorithm results. VANET supports various application types such as traffic jam notification, lane change warning, cooperative collision warning, blind curve ahead, and pedestrian crossing ahead (Kumar et al., 2022). A typical routing approach to support such applications may not be feasible. Researchers and academicians have classified these routing protocols according to their power-aware and predictive mobility abilities (Wahid et al., 2018). However, we classified the VANET routing protocols into three broader categories: transmission strategy network dimension and metric-based. Figure 2 presents a possible classification of these routing protocols with a few examples from each class. These routing protocols are based on V2V and V2I communication models and are suitable for limited applications. The following is a comprehensive overview of different VANET routing strategies:

2.1 Transmission Strategy

In a Vehicular environment, several transmission techniques can spread data packets from a source node to a sink node. One or more dissemination techniques may be managed using a routing protocol. Transmission strategy can be further classified into Unicast, Multicast, and Broadcast routing protocols which are described as follows:

2.1.1 Unicast Routing Protocols (URP)

The fundamental objective of VANET unicast routing is to transfer data from one source to a solo sink only. URPs are generally used to support comfort applications like watching multimedia content or commercial application like automatic toll collection. URPs use either a greedy forwarding technique or a carrying and forwarding strategy. In the greedy forwarding approach, intermediary vehicles in the routing path distribute data from a source to a destination as quickly as feasible. On the other hand, in the carrying and forwarding approach, intermediary vehicles can retain the data until the routing algorithm makes a forwarding decision. URP is further divided into three types: topology-based, position-based, and map-based routing protocols (Cheng et al., 2015).

- **Topology-based Routing Protocols (TBR)**

TBR protocols take advantage of the network topology and link data to carry traffic concerned messages up to the sink node. Source starts route discovery method and maintains a routing table containing details of intermediate hop to reach the destination. TBR is divided into reactive, proactive, and hybrid routing protocols. The reactive routing protocol (RRP) works on demand and floods route request messages into the network whenever required. Further, RRP can be categorized into source routing protocol (SRP) and hop-to-hop routing protocol (HRP) (Dua et al., 2014). SRP stores complete route information in packet headers, whereas HRP maintains the next-hop address and destination address. HRP provides a higher packet delivery ratio and lower delay than SRP. Dynamic Source Routing (DSR) (Maltz et al., 2007) is an example of SRP. RRP is more suitable for large-scale, frequent topology changes and highly mobile scenario networks. Temporally Ordered Routing Algorithm (TORA)(Nurwarsito & Umam, 2020) , Ad-hoc On-Demand Distance Vector (AODV)(Das et al., 2003) , and Dynamic MANET on Demand Routing Protocol (DYMO) (Chakeres et al., 2009) are a few examples of reactive routing protocol. The proactive routing protocol (PRP) uses a routing table to keep the latest route information of nearby neighbors of a node based on the shortest path algorithm. PRP protocols keep track of all nodes' routes, whether they are part of the network or not. A control message is issued on a regular schedule to keep network topology information accurate, so routes are already known when sending data packets to other nodes. If the network size increases, overheads of maintaining topology information also increase (Dua et al., 2014). Therefore, the control overheads are more in PRP than RRP; on the other hand, latency is high in the RRP protocol. PRP protocols can be classified into Distance Vector and Link State routing protocols. Destination-Sequenced Distance-Vector (DSDV) (Perkins & Bhagwat, 1994), Optimized Link State Routing (OLSR) (Clausen & Jacquet, 2003) come under distance vector routing protocols, and Fisheye State

Routing (FSR) (Guangyu Pei et al., 2000) belongs to link state proactive routing protocols. Hybrid Routing Protocols (HRP) utilizes the RRP and PRP properties to discover a route between the source and destination. In HRP, PRP discovers the route firstly, and then RRP takes care of the remaining processes. It decreases the routing control overhead in PRP and latency in RRP (Patel & Jhaveri, 2015). The zone routing protocol (ZRP) (Beijar, 2002) and zone-based hierarchical link state routing protocol (ZHLS) are examples of HRP.

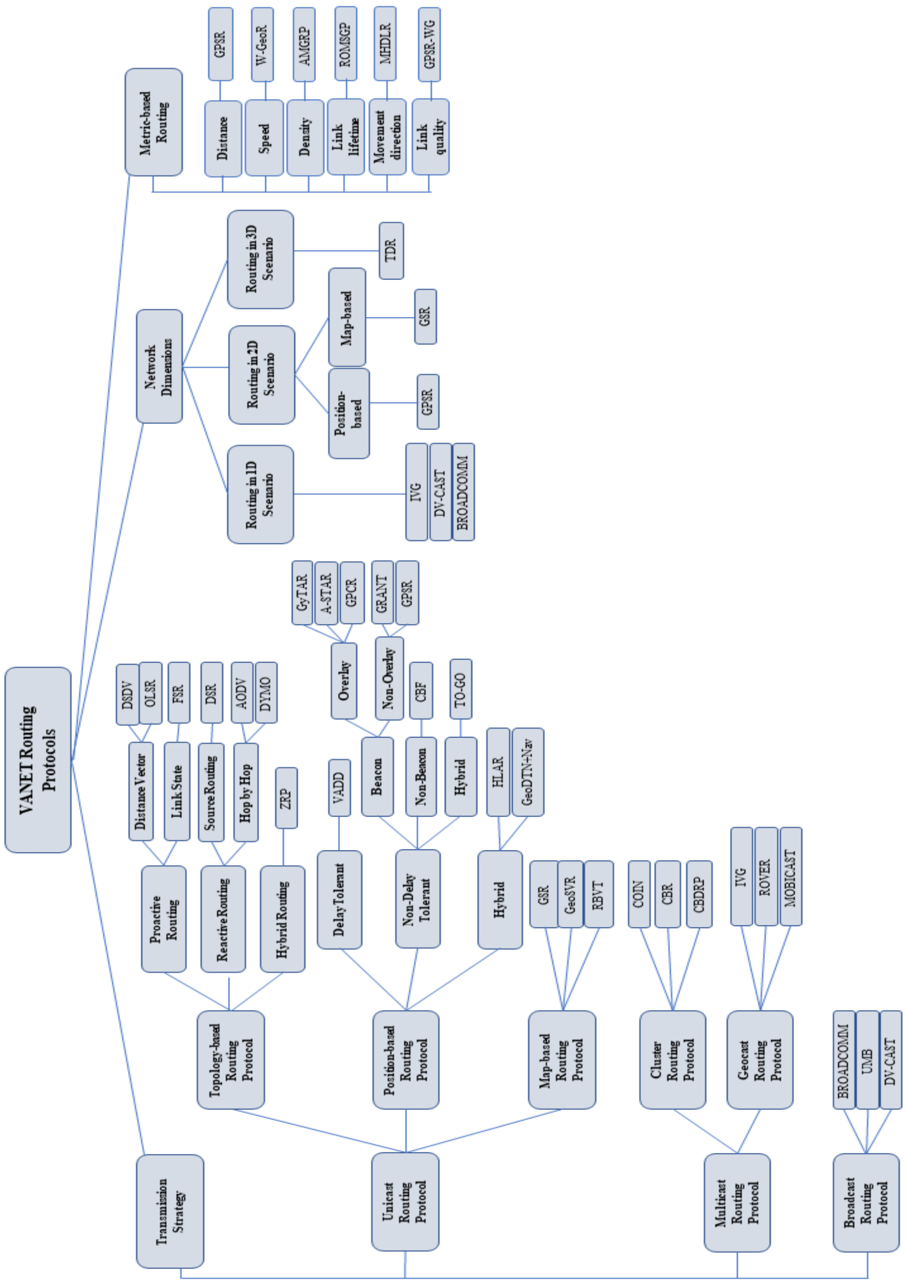

Figure 2. VANET routing taxonomy.

- **Position-based Routing Protocols (PBR)**

PBR routing protocols or sometimes called geographical protocols, assume that vehicles have preinstalled GPS devices that provide position data of themselves along with neighbors' position (Xiao et al., 2011). Because route selections are based on the neighbor and destination position data and global knowledge of network connections is not required, a routing table is not required to handle network connections in PBR protocols. If GPS or digital maps function correctly and provide accurate position data, overall packet losses and network partitions are reduced, but wrong location data may result in higher packet loss and network collision. Each node in the network sends out HELLO messages regularly to convey their present position. PBR protocols employ a greedy forwarding strategy to send packets to a destination. Greedy forwarding employs a loop-free routing approach that chooses the nodes as next-hop from its immediate neighbors closer to the destination node. It utilizes source, destination, and immediate neighbor position data for next-hop selection procedures to establish a route between source to destination (Vanthana et al., 2014). PBR protocols are classified into Delay Tolerant Network (DTN), Non-Delay Tolerant Network (Non-DTN), and Hybrid protocols.

(a) DTN Protocol

DTN protocol uses carry and forward routing techniques infrequently disconnected vehicular environments. When a node does not have other nearby nodes, the packet information is stored for some distance and forwarded when an opportunity arises (Karimi et al., 2011). DTN offers networking solutions for various network-related technical issues that may not possess continuous network connectivity. They are distinguished by latency, bandwidth, error probability, and route stability constraints (Jain et al., 2004). Vehicle Assisted Data Delivery (VADD) (Zhao et al., 2008) is an example of DTN protocols.

(b) Non-DTN Protocols

Non-DTN protocols use greedy forwarding strategies to reduce packet delivery time between source and destination. VANET safety applications necessitate a real-time response for warning message distribution; non-DTN protocols are best suited for safety applications. The shortest path technique is used to make routing decisions, in which the source passes a packet to its nearest neighbor. However, the shortest path does not enable quicker packet delivery in low-traffic environments and suffers from local maxima issues (Chen et al., 2009). These protocols are further categorized into beacon-based, beaconless, and hybrid protocols (Paul, 2012). Beacon-based protocols use beacons, i.e., hello packets regularly shared between nodes to provide information about location, velocity, direction, etc. This information is used by routing and MAC protocols and applications such as advanced driver assistance systems to perform route discovery, maintenance, and recovery. These protocols are classified into overlay and non-overlay protocols (Shah et al., 2018). It is referred to as an overlay routing protocol when any routing protocol operates on a group of selected nodes overlapping the entire network. Greedy Traffic Aware Routing protocol (GyTAR) (Jerbi et al., 2006), Greedy Perimeter Coordinator Routing (GPCR) (Lochert et al., 2005), and Anchor-Based Street and Traffic Aware Routing (A-STAR) (Seet et al., 2004) protocols belong to this category. Non-overlay protocols use a greedy approach in which the packet is sent to the one-hop neighbor, which is nearest to the destination position. Non-overlay protocols are ideal for VANETs because they provide a higher delivery ratio with a minimum delay than TBR protocols in a highly dynamic vehicular environment. However, because navigation data is exposed on the network, privacy is violated. Greedy Perimeter Stateless Routing (GPSR) (Karp & Kung, 2000), Position-Based Routing with Distance Vector

Recovery (PBR-DV) (Kirsch & Effelsberg, 2007), and Greedy Routing with Abstract Neighbor Table (GRANT) (Effelsberg et al., 2008) are a few examples of this category.

Because vehicles move fast in a VANET, the data supplied by hello packets can soon become invalid. Beaconless protocols do not employ beacon packets to track the location of neighbor nodes. Contention-based Forwarding (CBF) (Lochert et al., 2003) is a well-known example of this category. Hybrid protocols utilize the assistances of Beacon-based and Beaconless protocols in routing choices. Topology-assisted Geo-Opportunistic (TO-GO) (Lee et al., 2009) routing protocol belongs to this category. It chooses the next forwarding node using a greedy two-hop beaconing technique. Instead of the destination, CBF sends the packets to the specified node. The target node is chosen by the recovery or greedy algorithm, depending on the mode of operation.

c) Hybrid PBR Protocols

Hybrid protocols combine the best characteristics of DTN and non-DTN protocols. These protocols address network connection difficulties by functioning in perimeter, DTN, and non-DTN modes. These protocols switch from non-DTN to DTN mode by estimating network interconnectivity based on the total number of hops traversed by a packet, the neighbor’s transmission quality, and the neighbor’s movement towards the destination. GeoDTN + Nav (Cheng et al., 2010) and Hybrid Location-Based Ad-hoc Routing (HLAR) (Al-Rabayah et al., 2012) belong to hybrid protocols, which include a greedy mode, a perimeter mode, and a DTN mode.

- **Map-based Routing Protocols (MBRP)**

The MBRP routing method uses a street map or digital map information in forwarding processes. The geographical information of the one-hop neighbor, including speed, velocity, and direction, is used to make forwarding judgments. Geographical Source Routing (GSR) (Iwata et al., 1999), Geographic Stateless VANET Routing (GeoSVR) (Xiang et al., 2013), and road-based using vehicular traffic (RBVT) (Nzouonta et al., 2009) are a few examples of MBRP protocols.

2.1.2 Multicast Routing Protocols (MRP)

Multicast is a communication method in which the source node distributes data packets simultaneously to a set of nodes. It differs from broadcasting in which packets are transmitted to an individual or targeted network member. The primary goal of multicast routing systems is to disseminate information to groups and zones. MRP protocols are further subdivided into Cluster routing and Geocast routing protocols.

- **Cluster Routing Protocols (CRP)**

Cluster routing is concerned with establishing a network consisting of a small group of adjacent nodes known as a cluster. It is a small collection of nodes that identify themselves as cluster members. The size of a cluster is defined by specific routing algorithms depending on the location and number of nodes. Each cluster has one cluster head who is in charge of communication amongst cluster nodes. Clustering enables the cluster head to broadcast packets to the cluster, resulting in solid connectivity for huge size networks but increasing packet delay and overhead owing to the high mobility of VANETs. As network size and node mobility grow, selecting and managing cluster heads becomes time-consuming. The cluster head’s responsibilities include routing, inter-cluster traffic relaying, intra-cluster congestion management, and dealing with difficult situations (Lin et al., 1997). Cluster-Based Routing (CBR) (Luo et al., 2010), Hierarchical Cluster-Based Routing (HCB) (Xia et al., 2009), Cluster-Based Directional Routing Protocol (CBDRP) (Song et al., 2010), and Cluster-Based Location Routing (CBLR) (Santos et al., 2002) are a few examples of cluster routing protocols.

- **Geocast Routing Protocols (GRP)**

Location-based multicasting protocols come under the GRP. A data packet is transmitted from a sender node to all other nodes within a particular region in a Geocast-based routing system. This area is known as the zone of significance (ZOR). To deliver the packet to the other ZORs, these protocols employ zone of forwarding (ZOF) methods. The data packet is sent to the other ZORs by the nodes inside a certain ZOF(Huang et al., 2009). When packets are destined for destinations outside the sink area, the line forwarding mechanism or hop-to-hop delivery is employed. Geocast protocols are frequently affected by network partitioning, and packets may be routed to an undesirable neighbor, slowing the relaying process. The various Geocast based routing protocols are Robust Vehicular Routing Protocol (ROVER) (Rezaiefar et al., 2015), Inter-Vehicle Geo-cast Routing Protocol (IVG) (Benslimane et al., 2003), Distributed Robust Geo-cast Routing Protocol (DRG) (Joshi et al., 2007), Cached Geocast, and Dynamic Time–Stable Geo-cast Routing Protocol (DTSG) (Rahbar et al., 2010).

- **Broadcast Routing Protocols (BRP)**

To transmit safety-related information, weather conditions, traffic conditions, and promotions, VANET employs a broadcast-based routing system. Multi-hop flooding is used to achieve broadcasting, in which each node rebroadcasts messages to other adjacent nodes. Flooding can result in further data packet collisions, which consume more bandwidth and degrades overall system performance, so this approach is best suited for small networks. There are two types of broadcast routing protocols: single-hop broadcasting protocols and multi-hop broadcasting protocols (Kumar et al., 2012). The various broadcast-based routing protocols are BROADCOM (Durresi et al., 2005), Vector-Based Tracing Detection (V-TRADE) (Mangharam et al., 2006), Distributed vehicular broadcast protocol (DV-CAST) (Tonguz et al., 2007), Density aware reliable broadcasting protocol (DECA) (Na Nakorn & Rojviboonchai, 2010), and Parameter less broadcasting in static to highly mobile wireless ad-hoc (PBSM) (Khan et al., 2008).

2.2 Network Dimension

In a highly dynamic vehicular environment, making routing decisions is challenging, and the network dimension is critical. Frequent road topology changes result in incorrect next-hop selection, so network dimension must be considered during the route discovery process. VANET Routing protocols are divided into three groups based on network dimension: 1-D scenario, 2-D scenario, and 3-D scenario (Ksouri et al., 2020).

2.2.1 1-D Network Routing Protocol

It is the simplest routing technique that considers planar road network scenarios with two lanes and no junctions. Vehicles in separate lanes travel in the same or opposing directions. 1-D network scenario-based routing protocols serve as the foundation for researching complex VANET routing. Many broadcast and geocast routing methods are tailored specifically for 1-D network situations, such as Emergency BROADcast protocol for Inter-Vehicle COMMunications (BROADCOM) (Durresi et al., 2005), Inter-Vehicle Geo-cast Routing Protocol (IVG) (Benslimane et al., 2003), and DV-CAST (Cheng et al., 2015).

2.2.2 2-D Network Routing Protocol

These routing methods consider planar road network configurations with junctions that allow vehicles to drive in both directions simultaneously. 2-D network scenario-based protocols can be classified into position-based and map-based routing protocols. Position-based and map-based routing protocols belong to 2-D Network Routing Protocol which has been discussed in the above sections. Geographical Source Routing (GSR) (Liu et al., 2008), Geographic Stateless VANET Routing (GeoSVR) (Liu et al., 2013), Greedy Perimeter Coordinator Routing (GPCR) (Nishtha and Sood, 2020), Anchor-Based Street, and Traffic Aware Routing (A-STAR) (Seet et al., 2004) and DIrectional Routing (DIR) (Chen et al., 2011) belong to this category.

2.2.3 3-D Network Routing Protocol

When the Internet of Vehicles (IoV) is deployed in the near future, it will generate a very complex road topology, and IoV routing will be impossible to implement using existing routing protocols. This category of protocols addresses the difficulties posed by routing algorithms in 2-D network situations. It is based on a three-dimensional non-planer network scenario that includes the road's hierarchical structures. Routing decisions take into account the node's vertical orientation as well. Three-Dimensional scenario oriented Routing (TDR) (Lin et al., 2013) is a classic example of this category.

2.3 Metric-Based Routing Protocol

Various design elements and techniques were used by researchers in routing protocols to select the optimal route that takes into account more than one metric. Various metrics are in place to enhance routing methods for VANET communications, such as distance, movement direction, link quality, link lifetime, speed, and density (Tripp-Barba et al., 2019). Distance is employed to pick a next-hop node closest to the target as the most robust candidate node. GPSR (Karp & Kung, 2000) and Maxduration-Minangle GPSR (MM-GPSR) (Yang et al., 2018) is an example of distance-based routing protocol. Speed metric is used by routing algorithms to determine the link lifetime, movement direction, and link quality. It aids in the prediction of connection failure. W-GeoR (Singh et al., 2021) protocol uses speed metrics to predict node movement direction for health monitoring applications. Vehicles inside the communication range are called that vehicle's degree. Density metric helps predict route reliability, and frequent network disconnection might be prevented because of the high density in hop-by-hop selection. Analytical Hierarchical Process (AHP)-Based Multimetric Geographical-Routing Protocol (AMGRP) (Dharani Kumari et al., 2019) uses neighbor density in the beacon packet header. Vehicle movement is a crucial metric to consider while choosing a route.

Link lifetime is the shortest time it takes for two nodes in a network to exchange data packets. A longer link lifetime provides a more reliable routing path, resulting in lower packet losses. Receive on Most Stable Group-Path (ROMSGP) scheme (Taleb et al., 2007) consider link lifetime factor in forwarding decisions. If the source does not consider the traveling direction of the next- hop, it may make the incorrect forwarding choice by delivering packets to vehicles going in the opposite direction of the recipient. Multi-hop directional location routing (MHDLR) (Rana et al., 2020) considers movement directions and inter-vehicle distance to determine link reliability. Distance and signal quality-aware routing (DSQR) protocol (Qureshi et al., 2020) selects the best next forwarder node toward the destination node based on mid-area node selection; it assesses the direction and distance and neighbor connection quality for selecting the best next forwarder node. If there are no nodes in the mid-area, the source uses the carry-and-forward method to keep the packet for a certain period. Link quality metrics-based protocol prefers the link with the fewest transmitting vehicles, buildings, and obstacles that impact link quality between vehicles. GPSR-WG (Singh et al., 2021) considers link risk degree metrics to enhance GPSR protocol.

3. Summary

Developing efficient and robust routing protocols for VANET's application is a significant research challenge. A key research issue is the creation of efficient and resilient routing protocols for VANET applications. According to the literature study, the routing protocol's performance in VANETs is strongly affected by node mobility, vehicle density, and environmental events such as the traffic environment. It also depends on the correct mobility and propagation models being implemented. The protocol should work well in congested and dispersed traffic settings, such as cities and highways. As a result, creating a universal routing solution for all VANET application situations is highly challenging. To ensure that each application's QoS needs are met, the researcher must develop a customized routing protocol and mobility model. VANET applications are intrinsically hard in real-time, necessitating extremely low latency and reliable packet distribution. Previous works did not ensure QoS metrics such as packet drop rate, end-to-end latency, jitter, route stability, and so on. Existing routing protocols cannot handle more than one QoS parameter simultaneously. Routing protocols that may change their forwarding mode as per the application's demands require academicians' and researchers' attention.

Both unicast and broadcast protocols are utilized in safety and infotainment applications. Although flooding is an effective approach for such applications, it causes a broadcast-storm issue and network fragmentation. To solve these problems, an efficient broadcast protocol is required. VANET applications necessitate that the routing protocol scales effectively as the number of cars increases, and it must adapt to varied traffic circumstances without failures. Multicast and geocast protocols are recommended over flooding approaches to ensure end-to-end service quality. The expense of maintaining and disseminating the routing table in proactive routing protocols reduces the available network capacity. Reactive protocols find the pathways between nodes that are communicating on-demand, resulting in decreased path maintenance costs. TBR protocols did not scale effectively in the challenging VANET environment. CBR protocols are suited for area-based services since they allow inter-cluster and intra-cluster message passing. However, maintaining the varying cluster and selecting the proper head are complex challenges. The store and forward approaches are employed in delay-tolerant network protocols. It offers data delivery but suffers from high delay, making it unsuitable for VANET applications.

Because of the emergence of GPS-enabled intelligent vehicles, position-based protocols are becoming more prevalent for VANET. Moreover, position-based techniques are free of route creation and maintenance constraints. Two of the most common forwarding approaches employed by position-based protocols are greedy forwarding and perimeter forwarding. Due to the inconsistency of GPS location, position-based routing algorithms may fail to determine the precise vehicle location. Table 1 depicts a comparison of a few useful/important/popular routing protocols and their functionality in VANETs. The forwarding method, recovery strategy, delay sensitivity, network scenario, digital map, mobility model, and propagation model were compared (Venkatesh et al., 2014).

Table 1. Summary of VANET routing protocols.

Routing Category	**Protocol**	**Year**	**Forwarding Strategy**	**Recovery Strategy**	**Network Scenario**	**Digital Map**	**Mobility Model**	**Propagation Model**	**Delay**
Proactive	OLSR	2003	Multi-hop	Multi-Hop Forwarding	City	No	Random Way Point	Nakagami	More
Proactive	DSDV	2007	Multi-hop	Multi-Hop Forwarding	City	No	Random Way Point	Radio Propagation	Less
Reactive	AODV	2003	Multi-hop	Store & forward	Highway	No	IDM on Manhattan grid	Probabilistic shadowing	More
Reactive	DSR	2007	Multi-hop	Store & forward	City	No	Reference Point Group	Path Loss	More
Hybrid	ZRP	2002	Multi-hop	Multi-Hop Forwarding	City	No	Unknown	Unknown	More
Map-based	GSR	1999	Greedy	Flooding	City	Yes	Videlio, M-Grid	Road Blocking	Less
Geographic non-DTN	GPSR	2000	Greedy	Flooding	Highway	Yes	MTS	Probabilistic shadowing	More
Geographic non-DTN	GPCR	2003	Greedy	Flooding	City	Yes	VanetMobisim	Road Blocking	Less
Geographic non-DTN	CBF	2003	Greedy	Flooding	Highway	No	Random Way Point	Road Blocking	More
Geographic non-DTN	A-STAR	2004	Greedy	Flooding	City	Yes	M-Grid	Road Blocking	Less
Geographic non-DTN	GyTAR	2006	Greedy	Store & forward	City	Yes	Free Way	Free Space	Less
Geographic non-DTN	PBR-DV	2007	Greedy	Flooding	City	No	Unknown	Road Blocking	More
Geographic non-DTN	DIR	2011	Greedy	Store & forward	City	No	Random Way Point	Two-ray Ground	Less
Geographic non-DTN	TO-GO	2009	Greedy	Flooding	Highway	Yes	VanetMobsim	Road Blocking	More

Geographic non-DTN	GRANT	2008	Greedy	Flooding	City	No	Static trace from a uniform distribution	Road Blocking	Less
Geographic-DTN	VADD	2008	Opportunistic	Store & forward	City	Yes	Unknown	Unknown	Low
Geographic-DTN	OPERA	2009	Opportunistic	Flooding	Highway	Yes	Unknown	Road Blocking	More
Geographic-DTN	PDVR	2009	Opportunistic	Flooding	Highway	Yes	Unknown	Road Blocking	More
Geographic Hybrid	HLAR	2012	Greedy	Perimeter Forwarding	Highway	Yes	Random Way Point	Road Blocking	Less
Geographic Hybrid	GeoDTN + Nav	2010	Hybrid	Perimeter Forwarding	Highway	Yes	VanetMobsim	Road Blocking	Less
Cluster	BBR	2008	Opportunistic	Flooding	Highway	Yes	GTI	Road Blocking	Less
Cluster	CBLR	2004	Multi-hop	Flooding	City	Yes	Random Way Point	Road Blocking	Less
Cluster	HCB	2009	Greedy	Flooding	Highway	Yes	Random Way Point	Road Blocking	More
Cluster	CBDRP	2010	Multi-hop	Store & forward	City	Yes	Random Way Point	Road Blocking	More
Broadcast	UMB	2004	Multi-hop	Flooding	City	Yes	Free Way	Road Blocking	Less
Broadcast	BROADCOM	2005	Greedy	Flooding	Highway	Yes	Random Way Point	Road Blocking	More
Broadcast	DV-CAST	2007	Opportunistic	Store & forward	Highway	No	Random Way Point	Free Space	More
Broadcast	V-TRADE	2000	Opportunistic	Flooding	Highway	No	Random Way Point	Probabilistic shadowing	More
Geocast	ROVER	2007	Greedy	Flooding	City	No	Random Way Point	Road Blocking	More
Geocast	DRG	2007	Greedy	Store & forward	City	Yes	Random Way Point	Road Blocking	More

Geocast	IVG	2012	Greedy	Store & forward	City	Yes	Random Way Point	Road Blocking	More
Geocast	DTSG	2009	Greedy	Flooding	City	No	Random Way Point	Road Blocking	More
3D Scenario	TDR	2013	Greedy	Flooding	City	Yes	VanetMobi sim	Unknown	Less
Metric-based	MM-GPSR	2018	Greedy	Minimum Angle Forwarding	City	Yes	IDM on VanetMobi sim	Unknown	Less
Metric-based	AMGRP	2019	Greedy	Right-hand rule	City	No	Random Way Point	Two-ray Ground	Less
Metric-based	DSQR	2020	Greedy	Store & forward	City & Highway	No	MOVE Mobility	Shadowing	Less
Metric-based	MHDLR	2020	Opportunistic	Store & forward	City	No	MOVE Mobility	Unknown	Less
Metric-based	GPSR-WG	2021	Greedy	Perimeter Forwarding	City	Yes	Random Way Point	Two-ray Ground	Less
Metric-based	W-GeoR	2021	Greedy	Perimeter Forwarding	City	Yes	Random Way Point	Two-ray Ground	Less

4. Conclusion

The dream of an intelligent transportation system could be achieved by implementing VANET in the actual ground. VANETs have attracted the attention of academicians and researchers; therefore, extensive research has been conducted by industry and academia in the last two decades. VANET performs crucial information dissemination to drivers by using vehicle-to-vehicle and vehicle-to-infrastructure communication. Since VANETs are self-organized and distributed networks, developing a guaranteed information-delivering routing protocol is crucial. VANET applications are demanding in real-time and require guaranteed packets delivery with minimum delay.

This article discussed the importance and challenges of VANETs routing protocols. More precisely, this article provides a transmission strategy, network dimensions, and metric-based VANETs routing taxonomy. We presented the attributes of these routing protocols in the form of release year, routing category, forwarding strategy, recovery strategy, network scenario, digital map, and evaluating methods like mobility and propagation models. After analyzing the content of Table 1, we concluded that metric-based geographic routing protocols had gained popularity among researchers in recent years because of the digital map used by current vehicles. However, routing protocol efficiency in VANETs is strongly affected by node mobility, traffic density, and driving environment.

Many papers have been written that compare routing protocols in which one routing protocol beats the others in a particular mobility scenario and for a specific performance parameter. To meet the needs of various VANETs applications, special routing protocols must be designed, and accurate mobility and propagation models must be considered. Although routing in VANETs has gotten greater attention, several problems still have to be thoroughly studied. Routing protocol should work well in congested and dispersed traffic situations, whether in cities or highways. A single routing protocol for various VANET applications may not be practical, so the research community must focus on building a customized routing protocol and mobility model to fulfill application-specific QoS criteria. Newly designed protocols must include artificial intelligence, machine learning, and security mechanisms. Our future work includes developing multi-metric-based geographical routing protocols for health monitoring in urban vehicular environments.

Conflict of Interest

The authors confirm that there is no conflict of interest to declare for this publication.

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