

VANETs AND ITS RELATED ISSUES: AN EXTENSIVE SURVEY

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ABSTRACT

Vehicular Ad hoc Networks (VANETs) is a type of ad hoc network whereby its nodes are represented by vehicles. It originated from the desire to ensure drivers comfort and safety in road transportation so as to reduce the risk of accidents on the roads. VANETs have some unique features that make it different from MANETs in terms of characteristics, architecture, applications and challenges. This paper presents an extensive survey on VANETs and issues that are common so as provide necessary information and insight to developers and researchers in this field of research. The paper begins with ad hoc networks and ends with tools for VANETs simulation.

KeyWords: Wireless Access in Vehicular Environments, Mobile Ad hoc Networks, Flying Ad hoc Networks, Intelligent Transport Service, Vehicular Ad hoc Networks, Routing.

1 INTRODUCTION

VANETs emerged from the desire to encourage the growing range in wireless products which are used currently vehicles [20]. Such products include remote keyless entry devices, mobile telephones, laptops, and personal digital assistants (PDAs). As mobile networks and wireless devices become more and more valuable, the demand for V2I or V2V communication will definitely continue to develop [20]. [19] states that VANETs are often employed in a wide range of applications such as safety and non-safety; enable value added applications like traffic management, automated toll payment, vehicular safety, improved navigation, infotainment services such as having access to the internet and applications based on location such as locating fuel station, the nearest restaurant, or hotel. Over the previous couple of years, several research efforts in investigating numerous problems associated with V2V, and V2I have been witnessed which has to do with the important function they play in the ITSs (Intelligent Transportation Systems) evolution. Varieties of projects have been carried out on VANET by different industries, educational institutions, and governments across the world

within the past decade. This paper presents an extensive survey on VANETs and issues that are common so as provide necessary information and insight to developers and researchers in this field of research.

2 ADHOC NETWORKS

The rapid internet growth has made communication extremely important and an integrated factor of computing. In today's society with the advent of mobile devices, it has become vital to stay on-line all the time. Ad hoc can be seen as "Arranged or happening when necessary and not planned". Thus, it gives concise explanation of ad hoc networks, which implies that, it is a special purpose network established on the fly. Furthermore ad hoc networks are networks that are usually established for one time occurrences such as military operations or conferences. In order words, an ad hoc network is an adaptive and flexible network with no fixed infrastructure. Ad hoc network consists of mobile nodes like laptops, vehicles, sensor devices or PDAs that establish dynamic route to route data packets from one node

to the next accessible nodes. Generally, ad hoc networks can be classified into three (3) categories namely Mobile Ad hoc Network, Vehicular Ad hoc Network, and Flying Ad hoc Network. In all the categories, the network topology changes randomly and frequently. [35] show that VANETs have unique features which differentiate them from other types of ad hoc networks.

2.1 Mobile Ad hoc Networks

MANETs are effectively used in disaster recovery, and battle fields where the communication between network hosts are carried out via packet radios and routes are mostly multi-hop [4; 25]. One among the challenging issues in mobile ad-hoc network is routing. Previous protocols for MANETs can typically be classified into re-active and pro-active protocols. Facts have shown that, such protocols have some inherent weaknesses. These drawbacks includes: established protocols are restricted to given scenarios, thus, it does not do well in all scenarios; no adequate work has been carried out to evaluate other techniques of similar types with respect to their performances. Moreover, [4] proposed scheme focus on routing without considering their effects on some other routing related problems. MANETs are wireless multi-hop networks that are self organizing, whereby every mobile node participates in the process of communication. [54] assumes that every mobile nodes that participates in the process of communication act at the same time as both end devices and routers.

To overcome the issue of routing, it entails a demanding task of efficiently developing a routing protocol. In order to achieve a certain level of routing operation for MANETs, lots of routing algorithms have been developed. Routing is generally used in establishing and maintaining the routes from the source to destination [67]. Every node are mobile, hence topology frequently changes. Routing protocols thus, play a crucial function in ad hoc network communications. Routing protocols in MANET are divided into the following categories:

- a) **Proactive protocols:** In this protocol, each and every node within the network keeps a routing table of packets of data that are periodically broadcasted. The routes between the source and destination are calculated at a regular time intervals before the route that will connect the source node

and destination node. A source node sends information to a known destination by examining the routing table to obtain a match for the destination. Wireless Routing Protocol (WRP) [60], etc. are proactive protocol examples.

- b) **Reactive (On-demand) protocols:** The routes in these protocols are established only when the originating source node desire to send the information to a given destination, in order to reduce control packets overhead. Ad-Hoc On-Demand Distance-Vector Routing Protocol (AODV) [53], Location-Aided Routing Protocol (LAR) [32], Temporally-Ordered Routing algorithm (TORA) [51], Dynamic source Routing Protocol (DSR) [28], are examples of reactive routing.
- c) **Hybrid protocols:** This protocol combines both reactive and proactive routing techniques to route information from source to the desired destination. ZRP (Zone Routing Protocol) is an example of hybrid routing protocol.

2.2 Vehicular Ad hoc Networks

Recently, the number of cars is increasing by day. Additionally, the increase case of fatalities is as a result of the increased numbers of private transport. Exploiting dedicated short range communication (DSRC), VANET ensures that moving vehicles communicate wirelessly with each other. DSRC is originally comply with IEEE 802.11a standard and is improved to 802.11p to reduce operation overhead; hence, the entire groups of 1609 standards were standardized under IEEE and are referred as WAVE. Using WAVE technology, a vehicle can communicate with fixed infrastructure that is located by the road, which can be termed as road side unit (RSU) (also known as V2I) or communicate with other vehicles directly creating V2V communication [26; 46; 49]. These communications enable mobile nodes to exchange various types of information, for instance, safety information that can prevent accident, or traffic. Providing safety information to alert driver on time is the aim behind sharing and distributing this information.

Researchers from different field of studies are attracted to develop applications, simulation

tools, and protocols for VANET. Many challenges are faced by them and they try to deal with these problems. Security and privacy problem are addressed by [21]. [35] concentrate on routing protocols for VANET to obtain good communication time and thus, minimize bandwidth consumption of the network. Categories of routing in VANET are also addressed by [37] and the concept is associated to each of these protocols.

A lot of research activities have been highlighted by several conferences and research journals associated to VANETs [33; 56; 70]. In addition to traffic services and safety, VANETs also can offer some entertainment services which include downloading or uploading of information, electronic advertisements, and lots of different on-demand services. The speedy growth in information technologies and wireless communications are completely changing several aspects of our lifestyle. One area of application that is expected to benefit immensely from this development is vehicular safety.

In VANETs, vehicles that are situated within a particular region form a cluster. Every cluster is dedicated with RSU. When a cluster is being set up, vehicles of the cluster can communicate between one another and with the cluster's RSU. It is also possible for inter-cluster communication between vehicles belonging to adjacent clusters. Cars sharing the same interest or belonging to the same organization can form a cluster where they can communicate with one another and share information, which is another interesting application of VANETs. Despite the numerous interesting applications that VANETs provides, routing at the intersection has always been an issue. Several researchers [35; 38; 48] argue that MANETs routing protocols cannot be directly implemented in VANETs.

2.3 Flying Ad hoc Networks

Due to the fast technological developments on communication, sensor, and electronic technologies, it is feasible to provide Unmanned Aerial Vehicle that can fly independently or are often remotely controlled without conveying any person. Due to their ease of installation, flexibility, versatility, and comparatively little operational costs, the use of UAVs guarantees new methods for civilian and military applications, for instance border

surveillance of border, search and destroy operations [18], managing wildfire [5], wind estimation [10], relay for ad hoc networks [27], disaster observation [42], traffic observation [58] and remote sensing [68]. For decades, single-UAV has been in used, instead of creating and managing a large UAV. The use of clusters of single UAVs is of great advantages. However, one single UAV is restricted in terms of capability and hence, efficient collaboration and management of multiple UAV might produce a system which is more powerful than the ability of only a single UAV. Below are the benefits of multi-UAV systems:

- a) Cost: It is cheaper in acquiring and maintaining small UAVs than large UAV [8].
- b) Survivability: Its importance cannot be over emphasized. If the UAV stops working properly in a mission controlled by one UAV, implies that the mission cannot continue. But, when one UAV goes off in the process of a mission in multi-UAV system, it will survive the mission using the other UAVs.
- c) Scalability: Multi-UAV systems widens operational scalability with ease, however, the use of large UAV allows restricted amount of coverage [45].
- d) Small radar cross-section: Rather than using a huge radar cross-section, it is advisable to use multi-UAV systems because, it create very small amount of radar cross-sections, and its applications are seen in the military environment [65].
- e) Speed-up: Missions are often completed faster in a multi-UAVs environment [72].

FANETs are a form of ad hoc network like VANETs and MANETs. However, certain variations exist between FANETs and the other ad hoc networks in existence as follows:

- a) Mobility of nodes in FANET is far higher than nodes of VANET or MANET. Nodes in VANET are typically vehicles whereas nodes in MANET are walking men or devices. The nodes in FANET fly within the sky.

- b) Topology changes frequently due to high mobility in FANETs, than the topology of a VANET or MANET.
- c) The distances from one FANET nodes to the other are farther apart than VANETs node or MANETs node.
- d) Multi-UAV systems might embody differing kinds of sensors, and each of the sensing elements might need completely different data delivery methods.

3 CHARACTERISTICS OF VANETs

VANET has grown into an important research area over the past decades. VANET has its own distinctive features compared with MANETs as follows:

- a) High Computational Ability: Owing to the fact that the nodes in VANETs are vehicles, they are supplied with adequate sensors and resources for computation such as advanced antenna technology, global position system (GPS), processors, and large memory capacity. Computational capabilities of node are increased by these resources, which assist in achieving reliable communication, obtaining correct message concerning its current position, direction and speed [47; 49].
- b) Predictable Mobility: The mobility in VANETs is different from MANETs in whereby nodes in VANETs move randomly, because cars are usually restricted by the topology of the road and layout, thus are required to obey traffic lights, and road signs [7; 24; 35; 66] resulting to their movements being predictable.
- c) No Power Constraints: In VANETs, power is not a serious issue as in MANETs, due to the fact that cars can supply power continuously to OBU through the use of long life battery [24; 47; 73].
- d) Providing Safe Driving: This is achieved by improving traveler satisfaction and improving traffic efficiency. The direct communications between mobile nodes are ensured by VANETs, hence enabling the usage of set of applications that require

direct communication between vehicles over the network. These applications offer warning information to passengers moving along the same direction concerning the urgency for swift hard breaking or about accidents, thus the driver needs to create a larger image of road topology ahead. Furthermore, VANETs can also improve traveler satisfaction and improve traffic efficiency by proving information such as shopping malls, gas station, weather, traffic flow, and fast food [24].

- e) Variable Network Density: This depends on the density of traffic, which can be low, as in suburban traffic or high during traffic jam [66; 73].
- f) Large Network Size: The size of the network might be large in VANETs such as highways, urban centre, and when entering large cities [66; 73].
- g) Swift Distortions in the Topology of the Network: Vehicles moving on the highway, at a high speed, results to swift adjustment in the topology of the network. In addition, the information received can influence the behavior of the driver, as such results to changes in the topology of the network [35; 66; 73].

4 VANET TAXONOMY FOR COMMUNICATION PROTOCOLS

The applications in VANET require communication between cars to facilitate information circulation. Based on the characteristics of VANET, the following are VANET taxonomy for communication protocols:

4.1 Defining and Naming Issues

There are two (2) main kinds of multi-hop communications, which are geocasting (one-to-all in a given region) and routing (one-to-one). Applications requiring communication (either one-way or two-way) uses unicast routing to forward message from a node to or from a RSU, or the interaction between 2 nodes, for tracking a vehicle, managing response teams, or permitting the communication between two drivers. The application of Routing also include facilitating service providers to post their services, providing ITS services, ensuring the

connection of internet between service providers and users. The task of routing is an issue due to high mobility of node. The destination of information might be a fixed location, like road side unit, or a mobile vehicle with known position. Geocasting is a geographically restricted type of limited broadcasting. Information is disseminated to every car that is on the road or in a given geographical area. For example, the dissemination of content that is based on files being separated into multiple messages [34].

4.2 Dimension of Road

Several scenarios exist by which cars can travel on roads. Vehicles can travel on a highway without intersections. A road with two-direction with no intersections is referred to as one dimensional (1D). More generally, in urban regions, vehicles are placed in two dimensions (2D) where several intersections exist and a node may decide to change road on which it is moving. Intermediate scenarios also exist in which cars are constrained by roundabouts or junctions.

4.3 Neighborhood Knowledge

Some VANET protocols, forwarding decisions are made by vehicles without neighbor knowledge. However, in other protocols, it becomes necessary for nodes to learn and know its neighbors. Node could be aware of speed, and position of neighboring nodes. Such location knowledge of neighbor nodes becomes accessible during communication between nodes.

4.4 Acknowledgments

Acknowledgements are used to tell a sending node that the message sent has successfully been received. Beacon acknowledgment is used when a vehicle explicitly acknowledge receiving a packet when the vehicle adds the message it received to its regular beacons. Passive (implicit) acknowledgement is used when a vehicle estimate based on the distance, the reception of a packet from the sender.

4.5 Starting Forwarder Selection

Ideally nodes are usually in a state of being idle with respect to packets that are broadcasted. During the state of being idle, either a packet is not received so it not possible to retransmit or retransmission is not necessary for example the acknowledgement of receipt of

packets by all known neighbor nodes. Otherwise, the question is how a node determines whether the retransmission of a packet is necessary to cover certain nodes. As such, the process of starting forwarder selection of neighbor nodes to forward packets is initiated, and a state of being active with respect to the packet. The simplest decision of a forwarder selection method is that a node is in an active state whenever a packet is received [15]. Other alternative is to activate immediately when the packet is received for the first time and do not consider any further reception of the same packet [59].

4.6 Compete to Retransmit

Nodes that are active are a candidate for retransmission, but are not in the act of retransmitting yet. Vehicles normally negotiate the process of retransmission with neighbors. Negotiation is frequently carried by Time to Live (TTL), and waiting for the expiration of TTL. Active nodes ('winners' of forwarder selection) can enter into the state of transmission following a MAC layer protocol. However, vehicles to respond at different times due to certain delays which are introduced by medium access protocols. When one vehicle starts retransmitting, other vehicles must wait for the transmission to complete before continuing. The DSRC standard proposed is based on 802.11 kind of competition whereby vehicles wait for specific number of slots before it retransmits.

4.7 Connectivity

This is very essential in VANETs because disconnections of nodes are frequent event even in dense traffic [3]. In some protocol, nodes are assumed to be always connected. However, performance of this protocol is greatly affected should disconnection occur. Hence, different communication algorithms offer solutions for disconnection of node by providing alternative schemes like the store-carry-forward.

4.8 Urgency

Urgency is an essential metric of safety in which a packet should be sent with minimum time delay from a source to a destination. Safety applications such as crash warning demand that a packet be delivered within the shortest time possible, while non-safety applications demand reliability so as to achieve high packet delivery ratio. For instance, it is extremely urgent to forward a report concerning an

accident to incoming vehicles, it is still urgent (but considered less urgent) to forward the position of the accident to emergency centers.

4.9 Message Contents

VANET communication protocols address different types of message. It is classified into two 2. Full message is the first class referred to as the original message, which contains specific detail of information concerning the source and destination, such as the location of the source, location of destination, and speed [50]. A message in the second class might contain the forwarder ID so as to guarantee reliable and fast delivery of message [59].

5 VANETs NETWORK ARCHITECTURE

With the large increase of vehicles on roads recently, driving has become more challenging and dangerous. Roads are filled up with vehicles, reasonable speeds and safety distance are rarely adhered to, and travelers frequently lack adequate concentration. As such, leading automobile producers decided to collectively work with government organizations to come out with solutions geared toward assisting travelers on high ways by anticipating dangerous scenario or refrain from severe traffic regions. Meanwhile, the main objective is clearly to enhance safety of car traffic, onboard amusement applications and traffic management solutions are also anticipated by the various bodies (CALM) and projects (CarTALK 2000 [57]; VICS4 [71]; FleetNet [16]; CarNet [44]). The communication between V2V or between V2I is accomplished via wireless medium known as WAVE (Wireless Access in Vehicular Environments) [1].

5.1 On Board Unit (OBU)

OBU is mounted usually on-board of a node and is a WAVE device used for exchange of information with other OBUs or with Road Side Unit (RSUs). Normally, OBU is composed of a user interface, memory used for storing and retrieving message, a processor, an interface which serves as a link to different OBUs, wireless device for short communication range based on IEEE 802.11p. OBU connects to different OBUs or to the RSU via a wireless channel which is based on the IEEE 802.11p and it ensures the exchange of messages with RSUs or with different OBUs. The major tasks of OBU includes ad hoc and geographical routing, wireless radio access, information security, IP

mobility, reliable message transfer, and network congestion control [49].

5.2 Application Unit (AU)

AUs are devices equipped inside the vehicle which uses the services supplied by the provider by exploiting OBU capabilities. AU can be a PDA to connect to the Internet or a device dedicated for safety applications. A wired or wireless connection is used to connect the AU to the OBU and may be kept in one physical unit with the OBU. The difference between OBU and the AU is logical.

5.3 Road Side Unit (RSU)

RSUs are WAVE devices that are fixed in locations like near parking areas or junctions or on the road segment. The RSU is furnished with device that is dedicated for communication of short range based on the radio technology such as IEEE 802.11p, and for the aim of communication within the network infrastructure. RSU may be furnished also with different network devices as shown in Figures 1 to Figure 3. The major functions related to RSU according to C.C. Communication Consortium are:

- a) The range of ad hoc network communication is extended by redistributing the messages to different OBUs and by relaying messages to different RSUs so as to transmit it to different OBUs.
- b) It runs applications for safety such as work zone or accident warning, a low bridge warning, using V2I communication and it serves as a source of information.
- c) It provides OBUs with Internet connections.

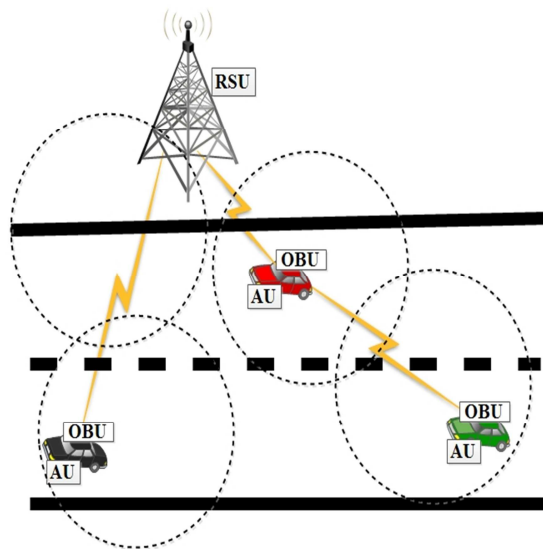


Figure 1: The ad hoc network communication range is extended to other OBUs by redistributing the messages [12]

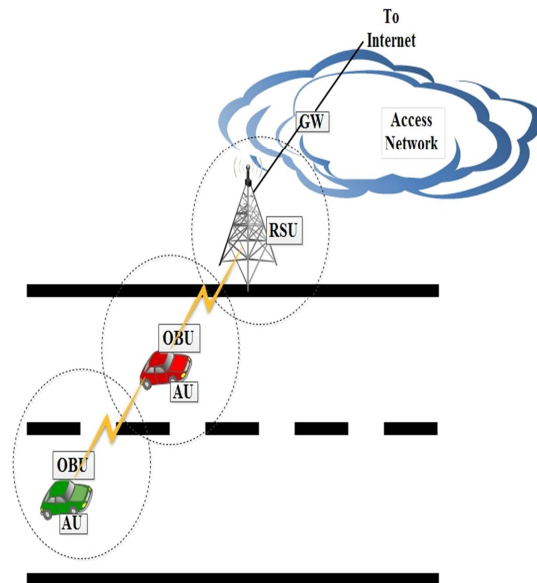


Figure 3: RSU provides OBUs with internet connections [12]

6 VANET COMMUNICATION DOMAINS

As shown in Figure 4, there are three types of domains for vehicles to communicate with the RSU and the infrastructure:

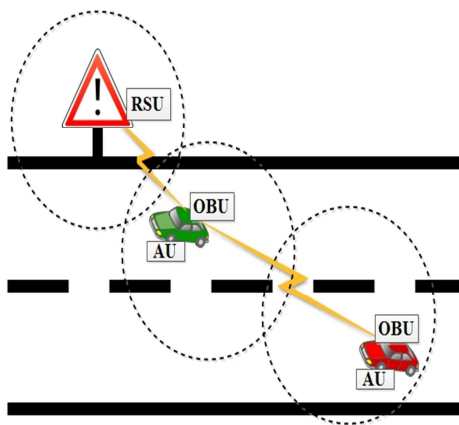


Figure 2: RSU runs applications for safety [12]

- a) **In-vehicle domain:** Includes an OBU with one or several AUs. A wired or wireless connection is used to connect the AU to the OBU and may be kept in one physical unit with the OBU. OBU provides a channel for communication to the AUs so as to execute some application by exploiting OBU communication capabilities [12; 14; 49].
- b) **Ad hoc domain:** Consists of cars that are equipped with RSU and OBUs. Two types of communications are obtainable as follows [14; 49]:
 - Due to its ability to enhance traffic safety on road, and efficient driving [39], vehicles use the OBU to communicate with one another, which enables distributed pattern of communication among vehicles with decentralized coordination.

- The RSU is used by vehicles so as to enhance communication range by sending and receiving information from a vehicle to another vehicle.

C) Infrastructural domain: RSU connects to the Internet, enabling the network infrastructure to be accessed by the OBU. As such, for the AUs to be connected to the Internet, it must be registered with the OBU.

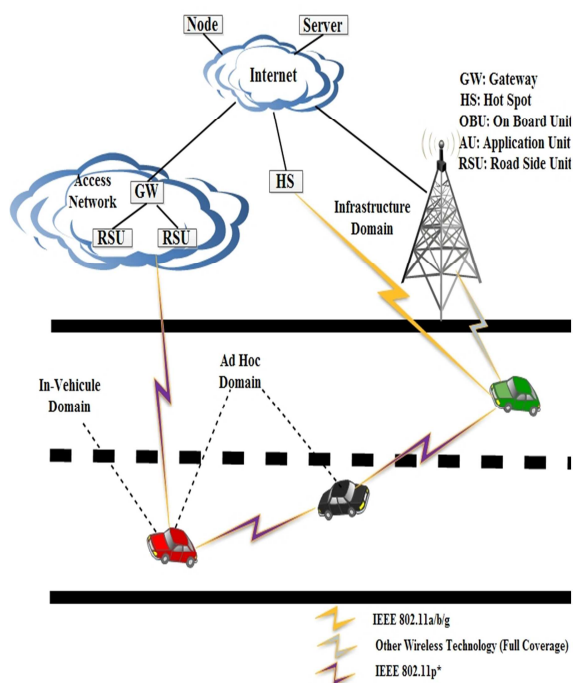


Figure 4: Communication Domains in VANETs
[49]

7 ROUTING PROTOCOLS IN VANETs

For decades, VANET has been studied and widely investigated [20; 63; 74]. Because VANETs are unique form of adhoc networks, most of protocols in MANETs have been examined and tested in VANETs. VANETs routing algorithms are usually categorized as topology-based and address-based which demands that every participating node is given a special address. Hence, a specific mechanism is needed to give special addresses to cars nevertheless; it is not a guarantee to avoid duplicate addresses in the network [43]. Hence, existing routing protocols used in MANETs are not applicable in VANETs environment. Related challenges such as mobility patterns, density of vehicles, network topology, rapid changes as a result in cars arriving and exiting, demographics, and the road width is sometimes smaller than the transmission range, makes the traditional ad hoc routing protocols inefficient. Figure 5 depicts classification of VANETs routing protocols.

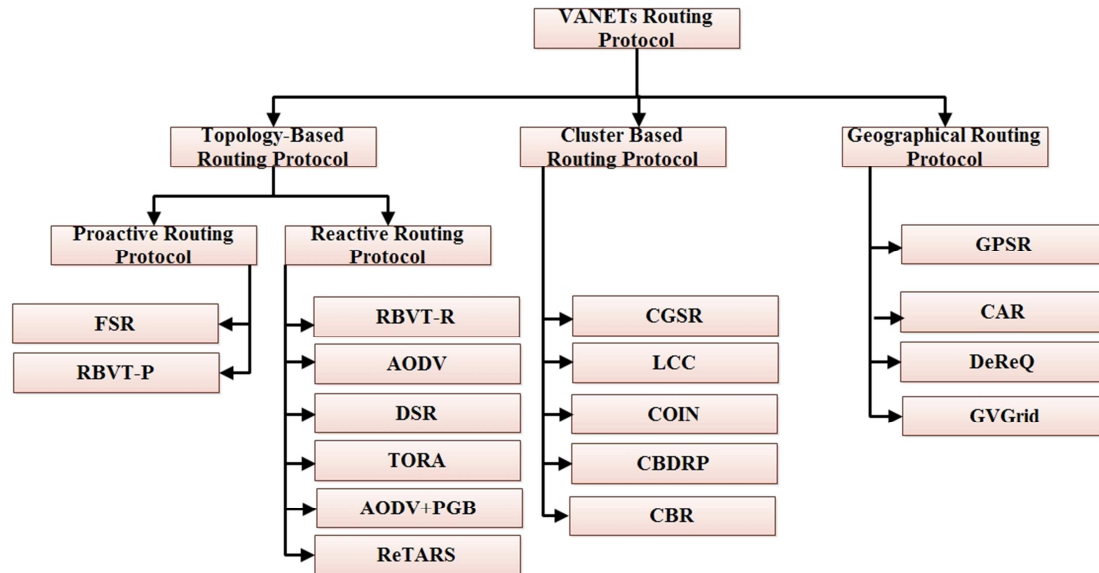


Figure 5: Classification of VANETs routing protocols

7.1 Topology-Based Routing

Packet forwarding is carried out by using links' information that exists in the network. Topology-based techniques [48; 53] take advantage of the information from obtainable network links for packet transmission and each node should keep information up-to-date with the routing table. In order to select a path from source to destination, topology-based routing uses links information formerly collected by the vehicle (table-driven or proactive) or required when needed (on-demand or reactive). Topology-Based routing is divided into reactive (on-demand) and proactive (table-driven) routing.

a) Proactive routing

Irrespective of communication requests, the next forwarding node routing information is preserved in the network background. In order to maintain the routes or link states, control packets are continuously broadcasted and flooded between vehicles though some of the routes created will never be used in the network. Within a node, a routing table is therefore created where every entry in the table of routing points to the direction of next hop toward the desired destination. Proactive

routing protocols do not require route discovery because path are usually maintained in the background that leads to the destination node and is accessible at all times upon lookup. In spite of its nice feature for ensuring low latency, the process of maintaining the paths that are unused occupies to a large extent the available bandwidth, particularly in VANETs environment where mobility is high. Examples of Proactive protocol include Fisheye State Routing (FSR) [23; 52], and Road-Based using Vehicular Traffic-Proactive (RBVT-P) [48].

b) Reactive routing

In reactive routing protocols, the routes are open only when nodes want to exchange information with another node. Reactive routing maintains only the currently used routes, thus the network burden is reduced. Typically reactive protocols use route discovery in which the network is flooded with query packets in search of a route. The route discovery phase is completed when a path is established. Examples of Reactive protocol include Road-Based using Vehicular Traffic-Reactive (RBVT-R) [48], Reactive Traffic Aware Routin Strategy (ReTARS) [30], DRS (Dynamic Source Routing) [28],

AODV (Ad hoc On Demand Distance Vector) [53], and TORA (Temporally Ordered Routing Algorithm) [51].

7.2 Clustered Based Routing Protocol (CBRP)

Vehicles that are close to each other make up a cluster in this type of routing protocols. The inter and intra-cluster management function is the responsibility of the cluster-head in each cluster. The Intra-cluster nodes exploit direct links to exchange information with each other, while cluster headers are responsible to ensure communication in inter-cluster. In CBRPs, the creation of clusters and cluster-head selection is a crucial issue. As a result of high mobility in VANET, the formation of dynamic cluster is an obvious process. K-Hop Cluster-Based Routing Protocol [11] improves CBRP with improvement in mobility as well as number of nodes. CBR (Cluster Based Routing protocol) [40], CBDP (Cluster-Based Directional Routing Protocol) [61], are the examples of CBRP.

7.3 Geographical Routing Protocols

Geographical routing generally refers to as position-based routing offers an adaptable routing elucidation for wireless networks. Ultimately, it is ordinarily a scalable routing technique intended for wireless networks, whereby the nodes will generate neighborhood routing selections that make the use of position information. In geographic routing, nearby neighbors within a region exchange position information is acquired through GPS (Global Positioning System) or any other location perseverance mechanism [69]. Geographic routing protocols are networking mechanism that distributes information to vehicles that are within a specified destination region. Therefore, routing protocols ensure information dissemination efficiently over several hops until each and every vehicle within the destination region receives this information [62]. Each car checks and examines if re-transmission is needed and implements it properly in an efficient manner. In this routing concept, the addresses of individual nodes are associated with their corresponding geographical position that is often used by sending vehicle to move data packets to the destination vehicle. Geographic routing possesses the advantage that should be much more adaptable as a consequence of

lesser desire for routing information. Thus its efficiency as well as adaptability make a decent choice for routing within multi-hop wireless networks [69].

Basically, geographical routing algorithms require knowledge about the location of the vehicles participating in the network. Thus, a sender can easily ask for the location of the receiver using a location service to forward the packet to the destination using different mechanisms. These however, include other related techniques such as greedy forwarding, hierarchical forwarding and Restricted Directional Flooding (RDF).

The most common method of geographical routing is through greedy forwarding packets for the neighbors that are geographically nearest to the destination. Despite the fact that the greedy technique is almost effective, packets might get routed to where no next hop neighbor exists which is closer to the destination and the void circumstance arise. Thus, the void problem occurs when there is no any node in the direction of the destination. Ultimately, several geographical routing techniques [17; 31; 35] are recommended with assorted forwarding techniques to select neighbors as the next-hop node. One example includes Greedy Perimeter Stateless Routing (GPSR) [29].

8 VANET RELATED ISSUES AND CHALLENGES

There are many challenges that arise as a result of running VANETs as an ad hoc communication among vehicles moving in a road environment. Hence, it is important to highlight the major issues in VANET, and from the technical perspectives, the key challenges are as follows:

- a) Routing protocol: Developing a routing protocol which will efficiently ensure packet delivery within little time frame with few packets that are dropped is considered as a serious issue in VANETs [9; 21; 37; 75].
- b) Small effective diameter: This results to weak connectivity during the communication between nodes due to VANETs small effective network diameter. Therefore, it is impractical to

- completely maintain global network topology for a node [22].
- c) Signal fading: This is an issue in VANETs which occur as a result of obstacles (or objects) which are placed between two vehicles that are communicating; such obstacles can be static objects such as buildings or moving objects such as other vehicles. The impact of these obstacles is the increase in signal fading and stopping the signal from getting to its destination [21].
 - d) Bandwidth limitations: In VANET, there is no central coordinator that is assigned with the responsibility of contention handling and bandwidth management. As such, efficient utilization of available bandwidth is very essential. Due to limited range in VANETs bandwidth frequency, the probability of channel congestion occurrence is high especially in high density environment.
 - e) Security and privacy: To maintain a balance between privacy and security is a big challenge in VANETs; it is important for the receiver to receive trustworthy message from its source. However, the privacy of the source can be violated by the trusted information [21].
 - f) Connectivity: The topology in VANETs changes rapidly due to high mobility, which results to frequent network disconnectivity. As such, the duration of time required to prolong the communication life of the link must be adequate. To accomplish this, the transmission power is increased; however, throughput degradation may occur.

9 COMMUNICATION TECHNOLOGIES IN VANETs

Presently, a lot of wireless technologies are available, which provide radio interface for vehicles to communicate with the RSUs (V2I communication) or each other (V2V communication). Such wireless technologies are aimed to enhance the comfort of driver and passenger, improve traffic efficiency, and to improve road safety. Some wireless access technologies include:

- a) Cellular systems: To reuse the available limited frequency is the idea behind cellular system [55]. Global system for

mobile (GSM) communication is described as a second generation (2G), provides data at the rate of 9.6Kbps [49]. GSM is seen to be a cellular system standard. GSM uses both FDMA (frequency division multiple access) and TDMA (time division multiple access) schemes. In GSM, the available frequency bands are 935–960 MHz and 890– 915 MHz for downlink (the connection from a larger network to a smaller network (or a device) is referred to as downlink) and uplink (the connection from a smaller network (or a device) to a network that is larger is referred to as an uplink) respectively. GPRS (General packet radio service) referred to 2.5G is a derived from GSM [24]. EDGE (Enhanced Data rates for GSM Evolution) is derived from GPRS [46].

- b) Combined wireless technologies: A set of wireless technologies like GPRS/GSM, are incorporated to Continuous Air interface for Long and Medium range (CALM), and are adapted to IEEE 802.11p [24]. Figure 6, shows that in addition to existing V2V, V2I, mixed mode (V2V and V2I), such technology creates new atmosphere for vehicular networking scenarios, which is made possible by the technologies mentioned above.
- c) Worldwide interoperability for microwave access (WiMAX): WiMAX or IEEE 802.16e is an improvement to the original WiMAX, which IEEE endorsed in the year 2004. Wide range of transmission and high data rate to ensure high quality of service (QoS) are made possible by IEEE 802.16e, thereby providing a suitable environment for those applications that needs these features for example VoIP, multimedia, etc. WiMAX uses Multiple-Input and Multiple-Output (MIMO) to achieve a high data rate [6].
- d) WLAN/WiFi: Wireless access to ensure V2I or V2V communication can be provided by WLAN/WiFi. In order to provide wireless connectivity, IEEE 802.11 standards can be applied; in IEEE 802.11a, it provides a data rate of 54 Mbps and runs at a frequency of 5 GHz. IEEE 802.11g is another standard for IEEE 802.11, which covers the same range and

provides the same data rate as IEEE 802.11a but runs at a frequency of 2.4 GHz [49]. Another standard is IEEE 802.11b, it provides a data rate of 11 Mbps and runs at a frequency of 2.4 GHz [46].

- e) DSRC/WAVE: DSRC originated from IEEE 802.11a. DSRC is improved for operations with low overhead in the DSRC spectrum and it is based on IEEE 802.11p [26; 46]. DSRC/WAVE provides a data rate of more than 27 Mbps, with 300m 1000m communication range, and moving at a speed of 200Kmph [24; 66].

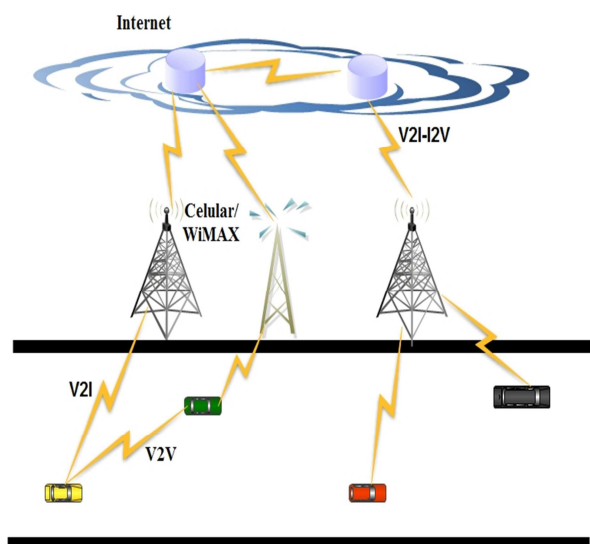


Figure 6: Wi-Fi, WiMAX, Cellular, and Combined DSRC in a single form [49]

10 VANET APPLICATIONS

Large number of applications can be developed due to V2V and V2I communications and can support wide range of information which is beneficial to travelers and drivers. Network interface and on-board devices can be incorporated, such as different types of GPS receivers and sensors enable nodes to receive, process, and distribute information about its environment and itself to other nearby nodes. As such, road safety and passenger's comfort are improved [24; 66]. Figure 7 shows the classification of VANET applications into their purpose as follows:

- a) Comfort applications: It is known as non-safety applications and the objective of this

application is to enhance passenger's comfort and to improve traffic efficiency. These applications make available to drivers with the location of petrol station, nearest restaurant, traffic information, nearest hotel, weather information, [24; 46; 66] etc.

- b) Safety applications: In order to avoid accidents and enhance road safety, these applications use the communication between V2I or V2V; the aim is to provide a good environment and to save lives. Figure 7, categorized safety applications as follows:

- ✓ Public safety: The aim of public safety applications is to assist drivers in case of accident and to assist search and rescue teams to provide services efficiently and minimize their travel time. The range of communication used by this application is 300 to 1000m and the frequency is 1Hz which depends on V2I, V2V or both [49]. For example, SOS services, Emergency vehicle signal pre-emption, etc.
- ✓ Collision avoidance at Intersection: Many road accidents can be avoided by improving collision avoidance at intersection which based on V2I communication. Information are received from vehicles approaching intersection, processed and analyzed by sensors at the infrastructure. After analysis on the data is completed, if the probability of an accident occurring, then warning signal are sent to vehicles arriving at the intersection warning them of the possibility of accident for them to take necessary and appropriate actions. For example, warning about violating traffic signal, etc.
- ✓ Sign extension: This is to warn drivers that are not paying attention to road signs which are stationed by the road side so as to avert road accidents. For example, curve speed warning, work zone warning, etc.
- ✓ Information from other vehicles: It depends on V2V, V2I or both in order to perform safety applications function and the range of communication used by this application is 50 to 400m and the

frequency is 2 to 50Hz [49]. For example, cooperative forward collision warning, etc.

- ✓ Diagnostics and maintenance of vehicle: This is used to send warning notification to vehicles with the objective of reminding the driver on the need for the vehicle to receive timely maintenance and about safety defects. For example, Just-in-time repair notification, etc.

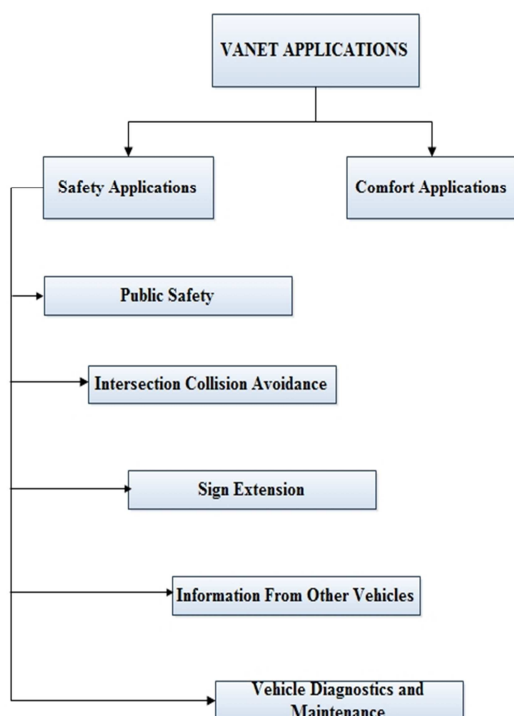


Figure 7: VANET Applications

11 NETWORK SIMULATORS

It enables researchers to observe how the behavior of the network would be under varied conditions. Hence, researchers can meet their demands by customizing the simulator. It is relatively cheaper and faster to use network simulators compared to conventional way of setting up an entire network consisting of routers, multiple networked computers, and data links. Thus, researchers can test scenarios at ease that might be too expensive or too difficult to emulate when real hardware are used, particularly in VANETs environment.

- a) **NS-2 [13]** is a discrete event simulator which was developed at University of California by group of researchers on VINT project. Monarch research group extended the simulator at Carnegie Mellon University by incorporating node mobility, radio network interfaces, IEEE 802.11 MAC (Medium Access Control) protocol, and a radio propagation model with physical layer.
- b) **JiST/SWANS [2]** is a discrete event simulator that runs over Java virtual machine. SWANS is a wireless network simulator that is scalable which is built on JiST platform. JiST simulation uses Java, standard virtual machine to run the simulations, and is compiled using Java compiler. When writing simulations, it does not require domain-specific language and must not be filled with system calls during runtime simulations. Rather, existing virtual machine are converted by JiST into simulation platform, whereby byte-code level is embedded in the simulation time semantics.
- c) **GloMoSim [41]** is both a wired and wireless network environment simulator that is scalable. GloMoSim is designed using the concept of layered approach which is similar to the OSI model. Rapid integration of different models are possibly developed by different researchers at different layers because, between separate simulation layers, APIs are used.

12 CONCLUSION

This paper surveys extensively all VANET routing protocols such as topology-based routing which performs packet forwarding by exploiting the links' information that is obtained in the network. Topology-based techniques take advantage from the information of obtainable network links for packet transmission and each node should keep up-to-date information with the routing table. In order to select a path from source to destination, topology-based routing uses links information formerly collected by the vehicle (table-driven or proactive) or required when needed (on-demand or reactive); cluster based routing where vehicles that are close to each other make up a cluster in this type of routing protocols. The inter and intra-cluster management is the responsibility of the cluster-

head in each cluster. The Intra-cluster nodes exploit direct links to exchange information with each other, while cluster headers are responsible to ensure communication in inter-cluster. In CBRPs, the creation of clusters and cluster-head selection is a crucial issue. As a result of high mobility in VANET, the formation of dynamic cluster is an obvious process. Cluster-Based Routing is an example of on-demand source routing whereby it tries to reduce control overhead by partitioning clusters into nodes in route discovery; and geographical routing also referred to as position-based routing which offers an adaptable routing elucidation for wireless networks. Ultimately, it is ordinarily a scalable routing technique intended for wireless networks, whereby the nodes will generate neighborhood routing selections that make the use of position information. Current issues of routing in VANETs are centered on resolving intersection issues in an urban vehicular environment. There are many challenges that arise as a result of running VANETs in order to provide an enhancement to driver behavior, so as to minimize the rate of fatalities caused by accidents. Hence, major issues in VANET are highlighted from the technical perspectives such as bandwidth limitations, signal fading, connectivity, small effective diameter, security and privacy, and routing protocol.

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