Review Article

Broadcasting in Connected and Fragmented Vehicular Ad Hoc Networks

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This paper starts with an overview of vehicular ad hoc networks (VANETs) and their characteristics. Then this paper reviews diverse applications of VANETs and the requirements of these applications. In addition it reviews VANETs standards, different broadcasting presented in a variety of studies, and also associated issues with data dissemination in connected and fragmented vehicular networks to solve broadcast storm problem and temporary disconnected VANETs. The discussion will be about the encountered challenges and presented solutions with respect to the related issues, based on the literature and strength and weakness of each protocol.

1. Introduction

Vehicular ad hoc network (VANET) establishes a wireless network among the vehicles (V2V) and, on the other level, between vehicles and infrastructure (V2I). VANET is a new technology that connects the vehicles on the basis of a short-range wireless communication (IEEE 802.11). For Dedicated Short Range Communication (DSRC), a band of 75 MHz in 5.9 GHz has been allocated by the Federal Communication Commission (FCC) [1]. DSRC helps the vehicles in VANETs to be in communication with each other and with the infrastructure. In DSRC, the GPS-enabled vehicles that are provided with on-board units connect to each other on a platform that is recognized today as the Vehicle Safety Communication (VSC) technologies. VANETs have the potential to contribute significantly to the future of vehicle communications.

VANETs are actually a particular type of mobile ad hoc networks (MANETs). The underlying philosophy is the same in both of these networks. However, a number of characteristics are specific for the VANETs that make them different from the MANETs. Compared with the other classes of mobile ad hoc networks, VANETs have unique characteristics. The main characteristics of the VANETs are as follows: time varying vehicle density, frequently disconnected network, heterogeneous communication range, mobility of the vehicles, geographically constrained topology, dynamic topology, and the vehicles being the components that build the network.

A variety of applications is provided by the VANETs [2]. There can be three major sections for these applications: commercial, nonsafety, and safety applications. The main objective of the vehicle safety communication consortium (VSCC) is the safety applications. These applications include situation awareness and warning messages. The aim of the nonsafety applications is driving efficiency and comfort improvement on the road. This improvement occurs through communication. The commercial applications include P2P file sharing, multimedia streaming, and internet access.

An effective and new class of communication applications is enabled by the DSRC. The safety of the road is improved by these applications. In Malaysia, similar to many other countries, one of the main causes of death is the fatalities of driving. The accident data record (Royal Malaysia Police) includes 6260 deaths, which were caused by 414,421 motor vehicles accidents in the year 2010 [3] and this is an example to indicate the severity of this problem. It has the third position by 8.3% among ten principle causes of death such as ischemic heart disease, cerebrovascular disease, road traffic injuries, lower respiratory infections, trachea, bronchus, and lung cancers, Nephritis and Nephrosis, HIV, breast cancer, diabetes mellitus, and colon and rectum cancers among

people in the year 2008 in Malaysia. Traffic accident has theh second place by 11.4% among the ten top causes of death for male and fifth place by 3.5% for female in Malaysia in 2008 [4].

There are different reasons related to accident on the roads such as high traffic volume, combination of traffic distribution, inappropriate design of the roads, and street lightning arrangement [5]. One approach to enhance safety is alerting the drivers about the risky situations which lie immediately ahead earlier than they reach the situation. These events may include incidents, accidents, or issues of traffic safety of any other kind. Many opportunities have become possible by transferring safety messages via communication capabilities of integrated GPS and on- board sensor devices.

Traffic information distribution is a unique problem in VANET. In most of the applications in VANET and safety applications in particular, there is no specific destination for the exchanged messages. In fact, the region of interest (RoI) for these messages is all of the surrounding vehicles and these vehicles are the targeted destinations. In other words, the public interest is the aim of these applications and, instead of a particular individual, a group of users are the beneficiaries of them. As a result, instead of using a unicast routing scheme to distribute the traffic information, the application of a broadcasting scheme is more appropriate. In a broadcasting scheme, the main advantage is that a route to a specific destination or the address of a destination is not necessary to be known to the vehicles. Therefore, the difficulties in dynamic networks, which can be addressed as the route discovery complexity, topology management, and address resolution, are eliminated. However, the blind broadcasting of the packets can initiate and cause conflict in the transmissions that take place between the neighboring vehicles. This is a problem that has been referred to as the broadcast storm problem [6, 7]. During the rush hour traffic, it is more likely for VANETs to form a highly dense network in urban areas or freeways.

Until now, the focus of most of the broadcasting research in VANET has been on analyzing the protocols in order to deal with the problem of the broadcast storm in a network with high density under an oversimplified assumption; a typical VANET is a connected network in nature [7]. However frequent network fragmentation is expected to be experienced by the VANETs during the late night hours or in the rural freeways of sparsely populated areas. Network fragmentation is also a significant research challenge that should be considered in VANETs. This paper is structured as follows: we review vehicular ad hoc networks characteristics, architecture, and applications in Sections 2, 3, and 4, respectively. Section 5 overviews packet forwarding and dissemination in VANETs. In Section 6, we give an overview of broadcasting protocol in connected and fragmented VANETs. We summarize our conclusions in Section 7.

2. Vehicular Ad Hoc Networks Characteristics

There is a potential for the vehicles to travel at high speeds. Therefore, the period of communication between them can be very short. Since vehicles have the characteristic of high mobility, the topology of the network changes so quickly and unexpectedly, which leads to the frequent and unpredictable break down of the wireless links [5]. Another feature of VANETs is that the network topology is highly dynamic [8]. For example, in late night hours or the rural freeways, the traffic density is in a very low level; on the other hand, in huge highways or at midday hours, a very dense network can be experienced. Accordingly, in the communication range, the number of neighbor vehicles may differ from zero up to hundreds.

Mobility of MANET is random and without certain controls [9], while in VANET nodes move throughout the network under some strict rules. This control strategy causes the position of vehicles to be predictable. One of the most important features of the vehicular scenarios is the fact that sensor nodes are not allowed to freely move around an area, and the vehicles have to be completely respectful of the movements of other vehicles and the road layout. That is, vehicles have a propensity to drive around the forming groups and the radio coverage of the wireless interface of the VANET is usually smaller than the distance between the groups. Furthermore, based on the kind of the road that vehicles pass on, the traffic patterns vary. The road topology also puts a severe restriction on the movement of the vehicle. In other words, while moving around, the nodes have to comply with those mobility patterns which the road network has imposed. Roads can be categorized into three groups: rural roads, urban roads, and highways. There are different kinds of roads as follows.

(i) Rural Roads. In a rural environment, the traffic density is expected to be low and therefore the resulting ad hoc network would be highly disconnected. This means that the network is partitioned into many little clusters (or groups of vehicles), which are not close enough to communicate directly. To overcome this, vehicles can route data packets to others by means of any existing communications infrastructure. Additionally, the average speed of the vehicles is expected to be moderately low.

(ii) Urban Roads. In this case, there are a moderately high number of vehicles which makes it easier to find a path from source to destination. These would run at moderately low or high speeds, depending on the specific road.

(iii) Highways. The traffic pattern is clearly different in this case, where vehicles are driven at high speeds following a road without crossovers or traffic lights. Thus, some regions are more populated and/or developed than others, which supposes a higher number of automobiles. The timeframe is also very important, because a low traffic density can be expected late at night, but traffic density would be extremely high during rush hours. Similarly, traffic conditions are different on weekends, on holidays, and when a special event, such as a concert or sports match, takes place.

Traffic density can be influenced by meteorological conditions or unexpected situations, such as accident or a street being repaired. To sum up, many factors come to play in
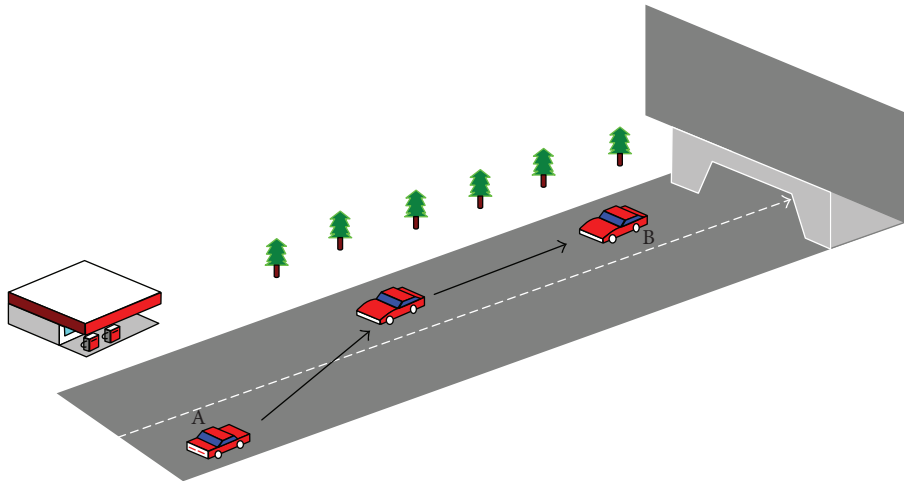
Figure 1: Vehicle-to-vehicle communication.

order to determine the mobility pattern of vehicles. Due to its high potential, the vehicular ad hoc network would be a significant part of the intelligent transportation system (ITS). Network operators are the service providers of VANETs. They can also be implemented with the collaboration of governmental authority. Recently, 75 MHz of DSRC spectrum at the frequency of 5.9 GHz has been allocated for the V2I and V2V communications by the Federal Communications Commission of U.S. (FCC) [1]. Seven wide channels of 10 MHz are the divided parts of the DSRC spectrum. This type of architectures should allow the communication between the equipment's of the roadside and the vehicles and among the vehicles that are nearby [10]. It means that there are no supports from any infrastructures. One other alternative is the technologies which are infrastructure based (V2I). In fact, the architecture of V2V is included in the V2I architecture. The approaches of V2I depend on the infrastructure that due to its high cost may not become a reality in early stage of VANETs development. Within the car to car communication consortium (C2C-CC) a reference architecture is proposed for the vehicular networks; this reference helps to distinguish between two domains: infrastructure domain and in vehicle ad hoc. Allocating unique DSRC spectrum, wide adaption of IEEE 802.11, popularity of Global Positioning System (GPS), and local regularity such as European Telecommunication Standard (ETSI), Industry Canada (IC), and FCC are major issues for rapid development of VANETs.

3. Vehicular Ad Hoc Network Architecture

Vehicular communication can be categorized to intervehicle communication and vehicle-to-roadside communication. Figure 1 shows vehicle-to-vehicle communication that used multihop broadcast or multicast to transfer information about traffic during multiple hops in a group of receivers.

Once a vehicle with a significant piece of information receives a query, the application responsible for sending a broadcast message regarding that piece of information immediately forwards it to the query source.

Figure 2 illustrates V2I communication. The configuration shown is a single-hop broadcast to a high bandwidth link between the vehicles and roadside units that sends a broadcast message to all surrounding vehicles. Furthermore, the roadside units assist high data rates in heavy traffic for each kilometer. For example, based on traffic conditions and internal timetables, the suitable speed limit for that section of the road at that time is determined limit in the broadcasting dynamic speed. As a result, the roadside unit will occasionally broadcast the speed limit message and will compare vehicle data with any directional or geographic limits to make a decision regarding sending a speed limit warning to any vehicles in the vicinity. If a vehicle exceeds the posted speed limit, the vehicle receives a broadcast in the form of a visual or auditory warning asking the driver to reduce his speed.

For the majority of VANET applications, the real-time updated information about the position is important to be accessible [11]. Unlike the other networks, in VANETs, the position information is probable to be completely accessible since they apply the GPS systems in the vehicles, which can be simply installed. By the application of GPS, locating the position of the vehicles is possible in VANET.

In VANET, there are thousands of nodes travelling at a speed up to tens of kilometres per hour. This feature is not accessible for any other mobile networks like the wireless sensor networks (WSNs) or mobile ad hoc networks [12].

4. Applications of VANETs

In the context of VANET applications, DSRC has been employed to develop new types of applications [2], which are benefited from combination of various hardware components (input and output devices, CPUs, navigations systems, sensors, and wireless transceivers) that will be employed in the future vehicles. These categories are driver safety enhancement, nonsafety utilization, and commercial intentions.

Safety applications are aimed at improving the public safety and protecting individuals against the events that may cause loss of life. In safety applications, the safety data is
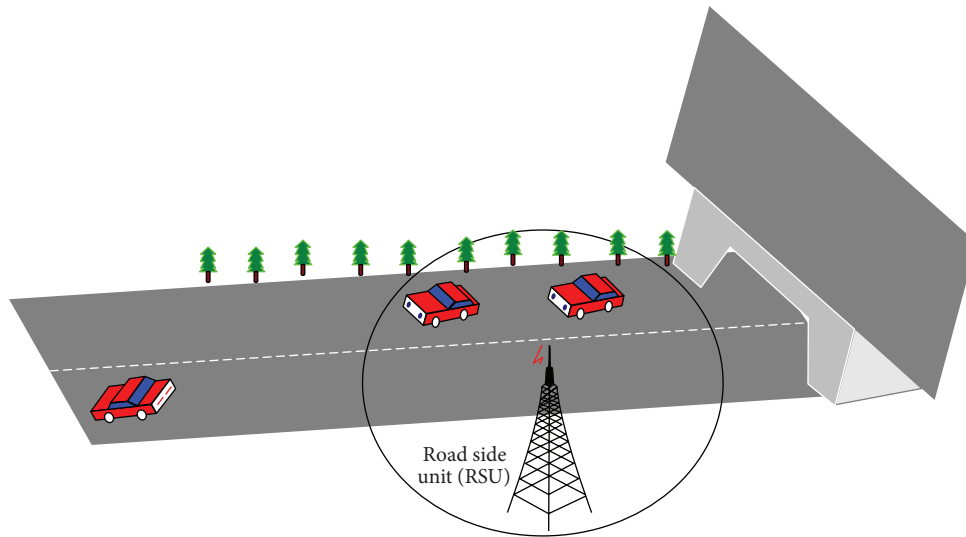
FIGURE 2: Vehicle-to-infrastructure communications.

required to be delivered by the intended receivers (e.g., those vehicles that are moving towards the dangerous zone). The most significant group of the VANET applications is the active safety applications which are aimed at decreasing the number of the fatalities or injuries in the road accidents. Safety applications broadcast the information about the risky positions and conditions like the Road Caution Hazard Notification (RCHN) or Post Crash Notification (PCN) to the vehicles that are positioned in a situation that can be benefited from that information in a way that they could keep away from an accident or any unwanted events. The active safety applications depend upon the information broadcasting into a certain geographical region [13]. Active safety applications are highly dependable on the information distribution into a particular area of interest. Although the messages sent by this application are relatively small and few, they essentially need to be delivered and distributed immediately and under very firm constraints [14].

The convenience and efficiency of the driver are improved by the nonsafety applications. As discussed above, safety applications do not deal with a lot of data volumes, but here, nonsafety applications need to take care of a higher volume of information [15]. The travel time is minimized by the driving efficiency applications. They distribute the information about the roads and the condition of the traffic on the roads so that the driver can avoid the high traffic density roads or even the roads with a traffic jam. Suppose that a driver needs to go on the road. If he has information about the roads which lead to his destination, he can greatly save his time by choosing the best route (by the application of the car navigation system), on which the traffic is not high. There are many situations such as merging into the flow traffic or finding free spot for parking that comfort applications, like the applications for the driver efficiency, which can help the driver. The information is periodically exchanged by nonsafety applications. Then they are aggregated with the information sensed by own sensors and obtained from the neighbor vehicles and, after all these

processing stages, the information is distributed to the other vehicles. Therefore, tight time is not imposed by them as safety applications do. However, they also need to periodically exchange information and data into the direct neighborhood.

There are some services that are provided by the commercial applications such as advertisement, web access, and entertainment. In addition, services such as map downloading (for the navigation systems), video streaming, and remote vehicle diagnostics are also included in these applications. Unlike the safety and nonsafety applications that are discussed previously, commercial applications are heavily dependent on the unicast communications [16].

The main objective of VANETs is safety messages and these messages must be at the highest priority and they need to have the on time delivery [15]. Since most of the safety applications rely on mechanisms of broadcast, they are delay-critical. These mechanisms let the information be distributed with the minimal delay [17]. Therefore, critical safety information has to be forwarded very quickly by the broadcast mechanisms that are designed for this purpose [15]. Technological advances have recently occurred in the vehicular ad hoc networks. However, VANETs suffer from some important challenges, including dynamic topology and high mobility of vehicles. Most of the time the topology of the VANET is changing because of the vehicles' high speed. The change in the connection of the nodes can be frequent for the same reason and this change can be unpredictable and rapid. Moreover, the number and distribution of vehicles on the roads may change in the network.

Usually, there is a very particular objective of providing an intelligent and safe transport system in the applications that are developed for the VANET [7]. Different from any other forms of the MANETs, There are different safety applications preparing convenient and intelligent transportation systems. Emergency warning is one of the public safety applications that require a broadcast protocol to disseminate the messages to target destinations. In high traffic densities, one of the
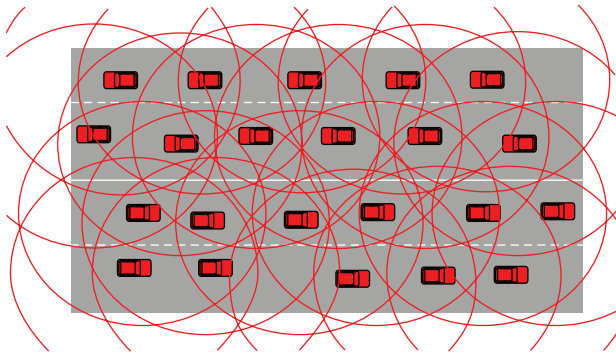
Figure 3: Broadcast storm problem [6].

significant and serious problems is redundant broadcasting. As a result broadcast storm problem occurs. Broadcast storm problem is a result of collision and contention in MAC layer. Because of excessive safety packet dissemination by different vehicles a contention in MAC layer and service disruption may happen [7]. Figure 3 shows an example of broadcast storm problem in VANETs. While vehicles broadcast the packets simultaneously, this is a serious problem in highways during rush hour or city scenarios.

Another critical challenge in a routing protocol design for VANETs is fragmentation [7]. In addition to research carried out on dense networks, there is an increasing demand for investigation on the fragmentation problem in sparse VANETs, in which the nodes are positioned sparsely, and, in these conditions, generally there cannot be found paths from source to destinations [18]. For instance in Figure 4, the distance between Vehicle A and Vehicle B is more than communication range of these vehicles; thus there is no connection between them. In order to design an efficient broadcast protocol for vehicular ad hoc networks broadcast storm problem and network fragmentation must be considered. Establishing a connection within a sparse network is very difficult, although, high mobility of the vehicular networks provides opportunity for the mobile vehicles to be connected with each other at the time that they are in motion.

Considerations of two main problems are necessary in the VANET broadcast protocol design. The first one is the broadcast storm problem and the second one is the temporary network fragmentation. The problem of the broadcast storm takes place when the transmission process is attempted by several entities in the network, and as a result, a serious packet collision occurs. The main objective of various broadcasting protocols in VANETs is to prevent unnecessarily rebroadcasting of the packet as much as possible. The second problem takes place when sufficient nodes are not provided in the area for the purpose of message distribution to transmit a packet thus the network may become fragmented. These two problems are well known among the research society of VANET, especially the problem of broadcast storm. However, the solution for each one of the problems was independent. The development of most of the proposed protocols was for the purpose of handling the problem of the broadcast storm or to deal with the problem of network fragmentation

separately. This paper is the first paper which reviews the solution for these problems separately and few protocols which solve these two problems simultaneously.

5. Packet Forwarding and Dissemination in VANETs

Monitoring the different applications that rely on the VANET reveals that a unicast communication needs to be established by a few numbers of the applications. Since the number of the nodes is very high and the topology of the network is rapidly changing, without knowing the receiver, the message sender can send messages. For sending messages, the sender does not need to know the receiver in the midst of the highly dynamic nodes, and it can send without changing quickly the network topology. In many cases, receivers can be defined, such as those located in front of or behind the sender, those in a particular spot, and those receivers that are able to offer a particular service. In addition, some of the applications are dependent on the local broadcast which can be considered as a type of one to all application: emergency signal preemption, SoS services, and postcrash warnings [12]. Therefore there are three categories for the communications in VANET: unicast, multicast, and broadcast.

6. Broadcasting in Vehicular Ad Hoc Networks

For the purpose of comfortable and safe drive for the vehicles, data can be exchanged among them in the vehicular ad hoc networks. There are numerous applications that have been developed and they depend on the distribution of data over long distances or in a geographical zone. Routing is about data packets delivery from the origin to the target over long distance via multihop steps (intermediate nodes). However, data dissemination refers to data distribution to all of the nodes in a particular zone. The main focus of data dissemination is on the delivery of safety related data to the safety applications, especially real time warning and collision avoidance. Although trying not to overload the network is one of the main goals of the distribution, one of the other essential issues is to ensure the delivery of the information to all of the necessary recipients in all the RoI.

One other way of looking at the broadcasting in VANET is to see it as a controlled flooding in the network. Suppose that there is a network with high density and in this high density network an event has been detected by the vehicles. Then vehicles try to inform the other vehicles about this event by broadcasting the data to them. Now, when there are numerous candidates to forward and broadcast this data, the overload of the shared wireless channel will occur. Therefore, there has to be a well-designed forwarding strategy so that the congestion of the wireless channel will not take place. In addition, the safety messages have the nature of broadcast and the on time availability of them needs to be ensured. Hence, in order to avoid the overloading of the channel, the number of unnecessary rebroadcasting needs to be minimized by the adopted techniques of data dissemination.
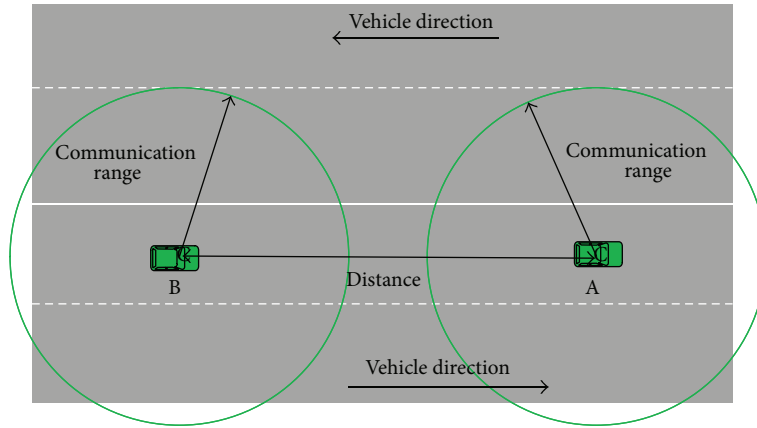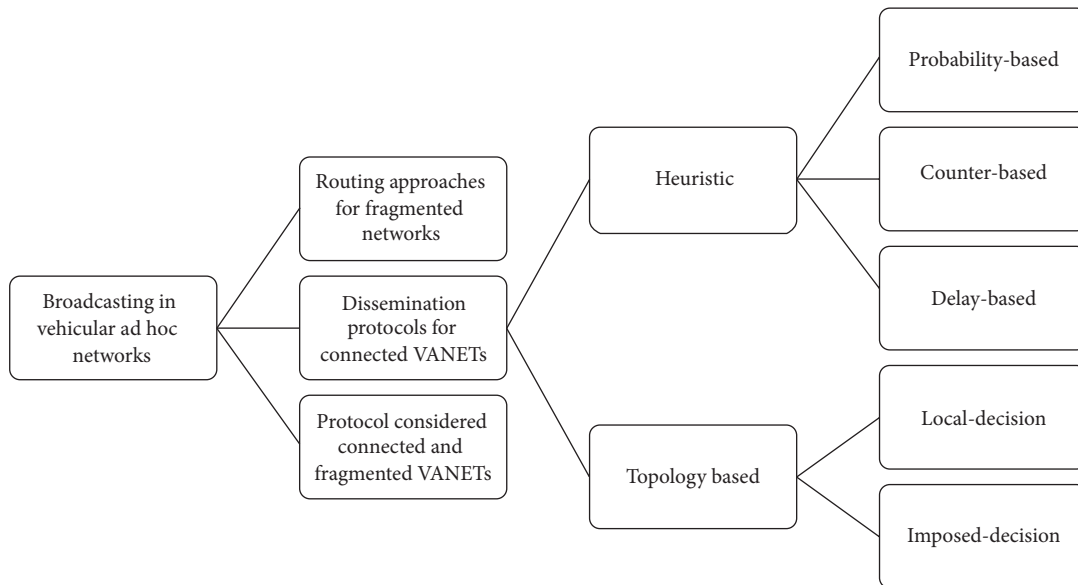
FIGURE 4: Network fragmentations.

FIGURE 5: Taxonomy of broadcasting protocol in vehicular ad hoc networks.

The classification of the protocols of broadcasting in VANET can be based on the network density assumption which has been shown in Figure 5. On this basis, there can be three different categories: the broadcasting protocol, which considers networks that are well connected, broadcasting protocols that fragmented vehicular ad hoc networks are considered by them, and the protocols that consider both of the fragmented and connected networks. A classification is shown in Figure 5. This classification is founded on the assumed condition of the network density. By using the particular assumed condition, each category corresponds to the protocols.

6.1. Dissemination Protocols for Connected Vehicular Ad Hoc Networks. For the broadcast packets, there are different protocols in VANETs. Flooding is the simplest technique. In the flooding technique, the packets are rebroadcasted by each

node at the time it has been received for the first time. Here, the broadcast total number is equal to $N - 1$ and N refers to the total number of the vehicles. Although flooding is a simple technique, it may become the cause of some issues. First, when a node tries to forward a data packet to the neighbors and they have received the packet beforehand, then redundant rebroadcast occurs and this would be a redundant transmission.

Second, there will be a contention at a medium level when a packet is received by a neighbor and that neighbor tries to rebroadcast the packet. This will lead to collision, redundancy, and contention in mobile networks. This phenomenon is referred to as broadcast storm problem. In this category, the protocol's main objective is restricting the rebroadcasting numbers, which will lead to broadcast storm problem mitigation. Topology based and heuristic based protocols are the categories of the protocols in this section.

6.1.1. Heuristic. The methods of heuristic broadcasting need parameter selection and thresholds selection, which are nearly associated with environments of ad hoc networks. The performance of these methods depends on the thresholds in the heuristic and the parameters that have been selected [6].

Probability-Based Method. In the method that is probability based, in order to reduce the redundancy of the packets and collision avoidance, the rebroadcast of the messages is decided by the vehicles with some probability. Static gossiping is one of the schemes that is probabilistic based and is used to enhance the flooding. In order to forward the messages, it applies a probability that is globally defined [19]. If the characteristics of the network are known in advance and static, all of these variants properly work. Otherwise, the result will be a low delivery ratio or a high number of messages that are redundant. Adaptive gossiping methods have been developed in order to make these problems go away. A scheme with two thresholds was proposed by Hass et al. [19]. For the static gossiping, this scheme is an expansion that is based on the count of the neighbors. If there are n neighbors for a node, this node will forward the data packet with the probability of $P1$. The n is the threshold and if the node neighbor's number becomes less than this threshold, then a higher probability of $P2$ is used to forward the messages. There is a considerable advantage to this improvement. This advantage is the dying prevention of the messages in the networks with sparse connectivity, because in these networks the forwarding probability is more than the forwarding probability in the dense networks. Hass et al. [19] have also proposed a second improvement, with which the dying out of a message is determined. If there are n neighbors for a node and the probability is p, then each message is received by each node $p \cdot n$ times from its neighbors.

Optimized adaptive probabilistic broadcast (OAPB) [20] is a probability based protocol designed to mitigate broadcast storm problem. In OAPB a rebroadcast probability is assigned to a node based on density of vehicles in its zone. For this purpose OAPB utilizes two-hop neighbor information. This information can only be accessed through one-hop neighbors.

Autocast Protocol [21] functions similar to OAPB. Rebroadcast probability in Autocast is calculated from number of nodes around the vehicle area. The only difference between Autocast and OAPB is using different equation to determine broadcast probability.

Counter-Based Method. In this method, there is a defined counter referred to by C and, each time that the same data packet is received by the node, the number of this counter goes higher. When the defined variable C becomes greater than a threshold, the node is dropped off the packet. During the time that the packet is dropped off and the first packet is received, the rebroadcast of the packet gets started by the node and it follows a little delay for each of the retransmissions [22].

A scheme that was counter based was proposed by Tseng et al. [23]. The mechanism of this scheme is that a random time out is set at the time that a message is received by a node for the first time. During the period of the timeout, a counter is increased for every duplicate message received. When the time out is expired, the message is forwarded if only the number of the counter has not passed a value for the threshold which is predetermined.

Delay-Based Method. In this method, in order to omit the retransmissions of the unnecessary information, smart flooding algorithms are used. With an effort of maximizing the nodes that are reachable, in order to forward the message, a set of nodes or a relay node is chosen instead of selecting all of the nodes to distribute the information to all of the neighbors. The methods that are relay based are able to deal with the problem of scalability of the nodes with high density.

Urban multihop broadcast (UMB) is a V2V delay based broadcasting protocol. This approach comprises two phases: the intersection and directional broadcast [24]. The road section that is within the communication range of the origin node is divided into subdivisions with equal lengths. The road that is in the direction of the distribution is the only road that is divided into subdivisions. The forwarding task is assigned to the vehicle from the farthest subdivision. However, in the scenarios with high density, there might be more than one vehicle in the segment in the farthest distance. In such cases, the subdivision that is the farthest one gets divided into subsegments that have width with smaller size. Then, in order to choose a vehicle that is in the farthest subsegment, a new iteration starts. When a request is received by the vehicles that are in the distribution direction from the sender and the request is to forward the received information, the distance of the vehicles to the source node is calculated by the vehicles themselves. According to the calculated distance, each of the vehicles transmits a jamming signal (black burst signal) in the period of the shortest interframe space (SIFS).

Transmission range adaptive broadcast (TRAB) is one of the other broadcast algorithms for VANET that are delay based [22]. This algorithm considers the communication range of the vehicles together with the inter vehicle distances. The waiting time is calculated by the TRAB algorithm in order to decide on the relay vehicles compliant with additional coverage area of neighboring nodes. This is to guarantee that there will be reduced number of relay nodes for the emergency packets forwarding. In addition, it adopts two types of mechanisms for answering to ensure the reliability of the distribution. These mechanisms are adaptively called explicit acknowledgement and implicit acknowledgement. The packets are forwarded by these mechanisms, founded on vehicles in the two-way lane.

6.1.2. Topology-Based Broadcasting. The broadcasting that is topology based is classified into two subcategories. These subcategories are imposed decision based and local decision based methods. In the methods that are local decision based (which are referred to as receiver based or reactive methods as well), the decision making of each node is on its own. This decision is whether to broadcast or forward a particular message or not. In contrast, in the approaches that are imposed decision based (which are referred to as sender based methods or proactive methods as well), it is the other

nodes that determine whether to forward a message or not. These other nodes can be the previous relay nodes or cluster head.

Local-Decision Approach. This approach is fundamentally based on the idea that the node exploits neighborhood connectivity and the history of the nodes that have been already visited by the message; this way, it can decide whether it is a forward node or not. A generic scheme has been proposed by [22]. Most of the local decision based methods that exist today are covered by this scheme. The base of this scheme is the neighborhood connectivity and nodes history, but only the nodes that have been visited before. The k-hop neighbors of each node have some information and this information will be built up by each node by exchanging information. This information will be exchanged via the Hello messages that are periodic and is between the one-hop neighbors. The node's property information such as node degree, list of the previously visited nodes, and the node ID is added to the broadcast message. According to this type of information, the decision of whether a message should be forwarded or not will be made. Flooding with self-pruning or neighbor coverage scheme is the most straightforward local decision based [25]. The list of one-hop neighbors of a sender gets piggybacked by the sender itself. This piggyback occurs on each one of the broadcast messages that gets transmitted. The message immediately gets forwarded, if some additional nodes can be covered by a receiver. The additional nodes are the nodes that are addition to those of the sender. A strategy for forwarding is used by the scalable broadcast algorithm (SBA), which is similar to the scheme of the neighbor coverage [26]. However, there are two differences as follows: first, the list of the nodes' one-hop neighbors is not inserted into data messages, but in the Hello packets. Secondly, the messages are not immediately forwarded by the nodes and the random assessment delay (RAD) is initiated by the nodes. During the period of waiting, the additional coverage is recalculated by the node for each neighbor forward. At the time that the random assessment delay expires, if the recalculated additional coverage has not reached the zero value, then that node is considered as a forwarder node. In the SBA, the adaptation of RAD is according to the neighbor degree of the node. One of the variants of the protocol of SBA is the Scoped Flooding. The condition of the forwarding is changed upon the expiration of the RAD. There are fixed ratios for each RAD and if the uncovered neighbors are more than this fixed ratio, then the message is forwarded by the node.

An algorithm is introduced by Stojmenovic [27]. There are only two-hop neighbors required by this algorithm. If there are two neighbors that are not connected, then the dominating set includes the node. The only nodes that forward the message are the ones that belong to the CDS. In order to detect if there are any connections between neighbors, the information of one-hop neighbor is enough. But this information will be enough if only the position of the nodes is known to the nodes themselves [27].

Imposed-Decision Protocol. In these protocols, there is a broadcast message from a sender, in which it is specified which neighbors have to execute a rebroadcast. These types of protocols are called the deterministic broadcast approaches. What the deterministic approaches do is that they clearly select a subclass of neighbors as the forwarding nodes. These selected neighbors can get to the expected destinations, which were supposed to be reached by all the nodes together. Therefore, there is a need for a relaying node to know at least its one-hop neighbors. Since finding a minimal sized optimal subset is considered as NP-hard, heuristic approaches are used. Therefore, the problem of the broadcast storm can be dealt with. That is the reason that there are different types of protocols of broadcasting, which are deterministic in the literature background.

There are some examples for the deterministic methods (approaches) such as cluster based methods [28], total dominant pruning, multipoint relaying (MPR) [29], and dominant pruning [30]. Although the deterministic broadcast has a high efficiency, there is also a considerable disadvantage for them. This disadvantage is that a single point of failure is represented by the relaying nodes. If for any reason, such as node failure, wireless losses, or not being in the communication range, the job of forwarding a message is failed by a relay, then it is possible that the message reception rate significantly drops. Therefore, there is a robustness lack in these types of protocols and their performance is poor in the environments that are dynamic such as VANETs. As a result, they are not suitable to be applied for robust and the safety critical applications in VANETs.

The main idea behind the multipoint relay (MPR) is a policy for a message to be forwarded [29]. In this policy a subset of one-hop neighbors of a node is selected by that node in order for the broadcast message to be forwarded. This process has to be performed in such a way that the two hop neighbors of the node can be reachable with this subset. In the multipoint relay, the list of the one-hop neighbors is inserted by the nodes into the Hello packets of the nodes. As a result, the awareness of the nodes from their two-hop neighbors is assured. The forwarder nodes are chosen from the one-hop neighbors of the sender node. Therefore, the set covers all of the two-hop neighbors. The forwarding list is piggybacked by the nodes in their beacons of Hello. The broadcast message is forwarded only by the nodes that exist in this list. Similar to MPR, by using Hello beacons, the nodes that exist in the dominant pruning obtain the knowledge about the two-hop neighbors. In addition, by utilizing the same rule of MPR, the designated forwarders are selected by the senders. Different from MPR, the forwarding set is selected by the receivers based on the selection rule of MPR. Besides, one other base for this selection is the knowledge of the previously covered neighbors by the broadcast of the sender. The selection of the forwarding set is out of the one-hop neighbors that are not included in the previous relay node's neighbors. The forwarding list is piggybacked on the broadcast message. Therefore, for a particular node, the forwarding message may be different from a message to another one.

Double covered broadcast (DCB), which is a broadcast scheme, was proposed by Lou and Wu [28]. There is a specific

policy for the forwarder node selection in the DCB. In this policy, first the two-hop neighbors of the sender are covered and then the one-hop neighbors of a sender are either a nonforward node or a forward node, but, in any case, at least two forwarding neighbors cover them. The results of simulation indicate that fine performance is provided by DCB for an operation of broadcasting under an environment with a high rate of transmission error [28].

6.2. Routing Approaches for Fragmented Vehicular Ad Hoc Networks. Since there are frequent partitions in the VANETs, the vehicles connectivity may not be present between most of the node pairs. In cases like this, fail of the many of the traditional broadcasting protocols is unavoidable. This part of the study will be assigned to the review of the fragmented networks' routing schemes.

In rural areas or at the night time when there is a light traffic, it is possible for the VANETs to become partitioned. The scenarios like this will happen at the times that there is a large distance between the nearby vehicles and this distance is greater than the communication range. Therefore, at some of the nodes the termination of broadcasting will occur [15]. In such scenarios of networking, as a capable scheme, it has been proposed to apply the store carry forward scheme. With the scheme of store carry forward, a packet that has been received by a node is stored and carried by the node while in motion and the node forwards the packet to the other nodes at the time that they come across.

6.2.1. Epidemic. The protocol of epidemic routing is for the delivery of messages in a network that is disconnected most of the times and has mobile nodes [31]. Each message has an ID and the summery vector of this ID is maintained by each node. But only the previously received message is maintained in each node. When a contact is initiated by two nodes, first exchanges are these summary vectors that exist in the session of antientropy. In this contact, the nodes compare the message IDs and then identify the messages that have not been received yet and determine whether or not the message has to be drawn from the other node or not. There is also a second phase for the contact; in this phase the messages are exchanged by the nodes. There is a limit for every message and this limit is referred to as the field of Time To Live (TTL). The number of the contacts that a massage can go through is limited by this field. When the value of the TTL for a message is "1," this message is only forwarded to the destination. The major problem of the epidemic routing is the flood of the messages that need to get to the destination in the whole network. This will result in contentions for the transmission time and the buffer space.

6.2.2. Vehicle Assisted Data Delivery (VADD). Vehicle Assisted Data Delivery (VADD) is for the purpose of sharing the idea of data packets storing and forwarding [32]. If the neighbor is not promising enough, they wait for another one, which is more reliable and is in their communication range. However, their effort is to forward the messages at the earliest time possible. In addition, by using the information of the

road and the vehicle, the decision where the packet needs to follow which one of the roads is made. This information is such as the maximum allowed speed, next junction distance, and the current speed.

The main objective of the Vehicle Assisted Data Delivery is to choose the path that has the minimum delay in the packet delivery. The node that holds the message has a position and this position affects the protocol's behavior. There have been two cases under consideration: when the nodes, which the message is routed by them, are in the middle of a road and when a junction is the location for those nodes. There are fewer alternatives for the first case, which is also referred to as routing in straight way. These alternatives are whether to forward the data packet to the previous junction or to the next one. However, the complication of the second case, which is also referred to as routing in intersections, is much more than straight roads. The reason of this complication is that there are different roads to be considered at the junctions and this leads to a higher number of options. In both cases, the applied approach is the same. This approach is to determine which road is the next one that the message needs to follow and after that, among the current neighbors, which relay has to be selected. To determine the next road, a common way has been proposed by the authors of VADD. The outgoing road, which its delay is the lowest, will be selected.

6.2.3. Spray and Wait. Spray and wait is a routing protocol with zero knowledge; it means that this protocol does not need neighbor information. To decrease the useless messages that are flooded in the DTN, this protocol was introduced [33]. Like the epidemic routing, the copies of the messages are forwarded to the nodes by this protocol. The major difference between these two protocols is that the total number of the distributed massage copies is restricted to a number N by spray and wait protocol and this number is a constant number. In the phase of spray, the nodes receiving the message (total number of N relays) and the source forward N copies for every message that its origination is the same source. In the phase of wait, direct transmission is performed by all the nodes that a copy of the message is stored by them.

At the start, the N copies of a particular message are spread by the spray and wait protocol and this takes place in an epidemic fashion. This is for increasing the possibility of having a direct contact of at least one relay node with the node of the destination. All the N copies of the message are forwarded by the source node to the first N encountered nodes. This can take place in a simple heuristic of the source spray and wait. The optimal policy for forwarding is the binary spray and waits. In this policy, the movements of the nodes are random and they have their own independent and identical distribution of probability. The storage of a message is physical and it will be transmitted only for one time, even at the times that multiple copies may be involved in a transmission. There is a header field for every message and the numbers of copies are indicated by this header. A binary tree, which its root is in the source node, can represent the paths that the copies follow.

6.2.4. MobySpace. In the MobySpace, it is more likely for two nodes with a smaller distance to have contact than two nodes that have a greater distance from each other. A message is decided to be forwarded by the forwarding algorithm. This decision is made during the contact to a node with a smaller distance to the destination of the message. The paths are taken through the MobySpace by the messages in order to bring the messages closer to the destination. There have been several proposed functions of distance for the similarity measurement in the patterns of mobility. The stable patterns of mobility are shown by the nodes, and then the approach of MobySpace can be effective. When there is a similar pattern of mobility for a current node with the destination, it is possible for the MobySpace to be ineffective. However, as a result of trajectory synchronization, it is rare to find a direct contact with the destination [34].

Although there might be similarity in the patterns of mobility in two nodes, it does not mean that there are frequent contacts. In addition, an effective path is not provided for the transmission of the messages by this similarity of mobility. There might be a solution for this problem and the solution can be the application of the frequency or the probability of the direct contacts with the other nodes as the distributions in the MobySpace. MobySpace with conversion of the spatial visit patterns to the frequency domain, demonstrate the dominant frequency and the phase. In this case, the frequency domain represents the phase and the main frequency of visitation. The other matters concerning the MobySpace include the effective distribution of location probabilities.

6.3. Broadcasting Protocols Considered Connected and Fragmented Vehicular Ad Hoc Networks. Just a few of broadcasting protocols have been developed to function in both conditions, connected and fragmented. This part will review these kinds of protocols.

6.3.1. Intervehicle Geocast (IVG). There is a distribution protocol for the safety messages in the VANETs, which is timer based and it is referred to as intervehicle geocast (IVG) [35]. If there are any incidents or any accidents in a highway, all the vehicles get informed by the IVG. The position and the direction of a vehicle are the factors that determine the areas of risk. For any incident or accident, the relevant areas are determined by this protocol. The broadcast group that is restricted is referred to as the multicast group. The direction of driving, velocity, and the location are the parameters that dynamically define a multicast group. The message received by the vehicles should not be rebroadcasted by them immediately. Before rebroadcasting, there has to be a defer time. If the vehicle has not received the message that has the same ID upon the expiration of the defer time, that vehicle appoints itself as a relay and commences to rebroadcast the message in order to inform the other vehicles. The defer time is calculated from

$$\text{defertime}(x) = \text{Maxdefertime} \cdot \left(\frac{R^{\varepsilon} - D_{sx}^{\varepsilon}}{R^{\varepsilon}} \right), \qquad (1)$$

where D_{sx} is the gap between nodes s and x and R is the communication range. The assumption of the IVG is that there is an equal communication range for all of the vehicles. The number of the unnecessary massages of safety is decreased by IVG. IVG performs this task by dynamically maintaining a relay in every driving direction. In addition, the safety messages are periodically rebroadcasted by IVG in order to concur the fragmentation of the network.

6.3.2. Distributed Robust Geocast (DRG). Distributed Robust Geocast (DRG) is an approach of broadcasting, which is fully distributed. The fragmentation of the network has been considered by this approach [36]. The zone of forwarding is defined by DRG and the region of interests is surrounded by this zone. The zone of forwarding is defined as a series of geographic areas that needs to be satisfied by the vehicles in order to forward a geocast message. The base of DRG is a back-off scheme and it is for the relay node selection. In addition, DRG is a protocol, which is thoroughly distributed.

After a back-off time that is distance based, for each node, a transmission time is scheduled by a vehicle at the time a safety message is received by that vehicle as follows:

$$\text{BO}_d (R_{tx}, d) = \text{Max BO}_d \cdot S_d \left(\frac{R_{tx} - d}{R_{tx}} \right). \qquad (2)$$

In (2), S_d is distance sensitivity factor, BO_d is back-off time, $\max \text{BO}_d$ is maximum back off time and R_{tx} is communication range. In order to deal with the temporary fragmentations of the network, DRG applies the packet periodic retransmission. This task continues until it is transmitted by a new relay. This is in fact the previous relays acknowledgment. When a node transmits a message at the time t, a retransmission is scheduled by that node at the time $t + \max \text{BO}_d$.

6.3.3. Distributed Vehicular Broadcast (DV-CAST). There are three techniques of suppression that the DV-CAST applies and they are light-weighted: slotted p-persistence, slotted 1-persistence, and weighted p-persistence [37]. In the three aforementioned techniques, instead of threshold values being used, in order to calculate the probability of forwarding and/or the waiting time that has to be passed before the rebroadcast, a light-weight distributed algorithm has been used. The technique of weighted p-persistence is actually a scheme that is distance based. The rebroadcasting probability is calculated by this technique by the relative distance that sits between two vehicles. The probability of forwarding P_{ij} is determined by (3). D_{ij} is distance from vehicle i and vehicle j and R is the communication range as follows:

$$P_{ij} = \frac{D_{ij}}{R}. \qquad (3)$$

In contrast with the gossip based scheme or the p-persistence scheme, there is a higher probability assigned to the nodes, which have more distance to the sender by the scheme of weighted p-persistence. This method is not aware of the density and, as a result, when there is a high density

in the network, the messages are rebroadcasted by the more distanced nodes.

6.3.4. Mobicast. For the cases in the highways, there is a broadcasting protocol called Mobicast. This protocol supports the applications of convenience and safety [15]. In the network, the zero infrastructure is assumed by Mobicast. At the time t, a message is distributed by the Mobicast to all of the vehicles in a particular zone from a particular vehicle. It is possible to divide the Mobicast into two different mechanisms, store carry forward and multiple forwarding. There are two different zones defined by Mobicast, zone of forwarding (ZOF) and zone of relevance (ZOR). The zone of forwarding is for the indication of the vehicles that have to carry the packet to forward and the zone of relevance is for the indication of the vehicles, which are the message receiver candidates.

6.3.5. Density-Aware Reliable Broadcasting in Vehicular Ad Hoc Networks (DECA). Density-aware reliable broadcasting in vehicular ad hoc networks (DECA) is designed for the urban and highway scenarios [38]. By utilizing periodic beaconing, the local density is gathered by this protocol. There are two lists for the DECA, list of broadcast and the list of neighbor. For all of the one hop neighbors, the identifier is the neighbor list. It also identifies their local density. The waiting time of the broadcast messages and the broadcast messages themselves are maintained by the broadcast list. DECA chooses a vehicle with highest local density to send a message. If the selected vehicle is the source vehicle, another vehicle will be choosen. A waiting time of each node is a random number.

6.3.6. Position Aware Reliable Broadcast Protocol (POCA). Position aware reliable broadcasting protocol (POCA) is a broadcasting protocol to eliminate broadcast storm problem in VANETs [39]. Also it is designed to function in intermittent connected network. It utilizes adaptive beaconing technique to obtain one-hop neighbor velocity and position information. POCA assumes that all the vehicles in the networks have homogeneous communication range. Relay selection in POCA is based on the distance between vehicles and selected node. The selected node instantly rebroadcast the packet. If the selected node does not rebroadcast the packet, other nodes will be chosen as an alternative. In POCA, waiting time is calculated based on the distance between precursor node and the vehicle.

6.3.7. Efficient Directional Broadcast (EDB). EDB is broadcasting protocol which is directional and distance based for the urban vehicular ad hoc networks and it applies the directional antennas [40]. In the EDB, the responsibility of distributing the message when it arrives in the zhighways opposite direction is for the furthest receiver. Fixed directional antennas are the equipment of each vehicle in EDB and the beam width of these antennas is about 30 degree. There are two pointing for these antennas to be mounted with, one at the back and one at the front. Since the vehicular ad

hoc networks have a highly dynamic mobility, receiver based decisions are made by the EDB in order to packet forwarding in the direction that is the opposite direction of a highway. EDB calculates waiting time from

$$\text{WaitingTime} = \left(1 - \frac{D}{\text{TR}}\right) * \text{maxWT}, \qquad (4)$$

where TR is the communication range, D is distance from the source, and maxWT is the maximum waiting time. The last vehicle sends an acknowledgement to notify the sender.

6.3.8. Simple and Robust Dissemination Protocol (SRD). For highway cases, a Simple and Robust Dissemination Protocol (SRD) is a protocol for the broadcasting purposes [41]. Vehicle-to-vehicle communication is assumed by Simple and Robust Dissemination protocol. In SDR, a time slot assignment is the Optimized Slotted 1-Persistence. This technique operates as follows: when the vehicle j is moving in the direction of the message, a message is received by this vehicle from the vehicle i. Then the PD_{ij} distance is calculated based on (5) which is the distance between the two vehicles which is calculated. SRD assumes that communication range of the vehicles is same. Consider

$$PD_{ij} = \left[\frac{\min\left(D_{ij}, R\right)}{R}\right], \qquad (5)$$

where R is the communication range and D_{ij} is vehicles i and j distance. The number of time slot S_{ij} assigned to vehicle j is calculated by

$$S_{ij} = \left\lfloor \text{NS} * \left(1 - PD_{ij}\right)\right\rfloor, \qquad (6)$$

where NS is the whole number of time slots. The vehicles are divided into two different categories by the SDR. Tail states: the vehicles that do not have any connection with the other vehicles, which are located in the greater distances in the direction of the message, are referred to as the cluster tail. Nontail states: there is at least one neighbor for the vehicles that are categorized in this state. There are two responsibilities for the vehicles, which are classified in the second category. The vehicle in the message direction just rebroadcast the packet and those vehicles which are not in the message direction will drop it.

6.3.9. Edge Aware Epidemic Protocol (EAEP). Edge Aware Epidemic Protocol [42] is designed for VANETs to solve broadcast storm problem in highway. EAEP is an epidemic protocol which assumes end to end connection between vehicles. It decreases overhead by omitting beacon exchange. EAEP utilizes GPS to determine the location information of each vehicle. Each node piggybacks its geographical location upon receiving a new packet in broadcast message to withdraw Hello packets. Each node has assigned a random waiting time. This waiting time is selected exponentially based on the

distance from the source. This random waiting time is chosen from interval $[0, T_{\max}]$ with

$$T_{\max} = \min \begin{cases} \dfrac{T_0}{U} \exp\left(\dfrac{|x_{\text{rec}} - x_{\text{sou}}|}{L}\right), \\ T_{\min} = \dfrac{T_0}{2U}. \end{cases} \tag{7}$$

In (7), U is used to indicate "Urgency" of the packet and T_0 and L are parameters related to the protocol. While assigned waiting time expires, the vehicle counts number of received packet from nodes in the front and the back. Then this vehicle makes a proper decision to rebroadcast the packet or not based on the difference between count numbers.

6.3.10. Acknowledgement Parameter Less Broadcast in Static to Highly Dynamic Mobile (ACK-PBSM). In order to broadcast in the networks with good connections, the dominating set that is connected is used by Ack-PBSM. It can be applied in both scenarios of urban and highway cases [43]. The parameter less broadcast is extended and this protocol is one of the extensions. However, this protocol is in the highly mobile and static scenarios (PBSM) [26]. The broadcast packet's acknowledgment is handled by this protocol. In periodic beacons, these acknowledgments are piggybacked. There is a function referred to as toev and the waiting time is assigned by this function to each vehicle before there is any retransmission possibility. The value of toev can be calculated from

$$\text{toev} = \frac{1}{|N|}, \tag{8}$$

where $|N|$ is the number of elements in N and indicates whether the node is in the CDs or not. In order to deal with the temporary network fragmentation, the store carry forward approach is applied by this protocol.

6.3.11. Urban Vehicular Broadcast (UV-CAST). Urban Vehicular Broadcast (UV-CAST) is an urban scenario designed broadcast protocol [44]. The assumption of this protocol is the vehicle-to-vehicle communication and there is no support of any infrastructures involved. There are two ranges of transmission for the communications of Nonline of Sight and Line of Sight (LOS). In this protocol, the only way that there can be communication between two vehicles is that they are in the corresponding range of communication. The node that has the shortest healing time is assigned with the task of store carry forward. When a message is received for the first time, the angle θ is computed by the node for all of its neighbors. Maximum (θ^+) and minimum (θ^-) angels are then computed from (9), where

$$\theta^- = \min\left(\text{mini}\left(\theta_i\right), 0\right),$$
$$\theta^+ = \max\left(\text{maxi}\left(\theta_i\right), 0\right). \tag{9}$$

If

$$\left|\theta^+\right| + \left|\theta^-\right| < \pi \quad \text{then } A = \text{SCF Task.} \tag{10}$$

The boundary vehicles are selected by (10) for UV-CAST from θ^+ and θ^- angles in order to be assigned to the task of store carry forward. An overhead and a high complexity are given to this protocol by this process. The task of store carry forward is assigned to many vehicles to be performed in the high and medium densities of traffic. UV-CAST uses a timer based approach and, while a new packet received, the vehicle computes the waiting time based on (11). UV-CAST uses two independent equations for highway and intersection:

$$T_i = \begin{cases} \dfrac{1}{2}\left(1 - \dfrac{d_{ij}}{R}\right) T_{\max}, & \text{If } i \text{ is at intersection,} \\ \dfrac{1}{2}\left(2 - \dfrac{d_{ij}}{R}\right) T_{\max}, & \text{otherwise,} \end{cases} \tag{11}$$

where $T_{\max}$ is the maximum of the waiting time, R is the communication range, and d_{ij} is the distance that sits between the vehicle j and vehicle i. At the time that expiration time of the timer comes up and any duplicate packet is not received by the vehicle i, the rebroadcast is performed by the vehicle i, and, in the other cases, the packet is dropped by the vehicle i.

6.3.12. Streetcast. Streetcast is an urban broadcast protocol for VANETs to solve broadcast storm problem which assumes a homogeneous communication range for vehicles. There are three components, of which the streetcast (considered as a broadcast protocol of VANET) is comprised: adaptive beacon control, Multicast Request-To-Send (MRTS) handshaking, and relay node selection. For the relay node selection, the information of one hop neighbour and the information of the digital street map are applied. The mechanism of MRTS is used for the protection of the transmissions of the messages. For the information exchange between the neighbors, the "Hello" beacons are utilized. Meanwhile, there is a proposed adaptive beacon control heuristic for the dynamical adjustment of the number of the transmitted beacons. For the redundancy reduction, the multipoint relay (MPR) is applied as the strategy of broadcast for the reduction of the relay nodes number. Since the distribution of the vehicles is along the streets, the MPR selection can be simplified by applying the digital street map. A neighbor table is maintained by each Road Side Units (RSU) and On-Board units (OBU). For the direction of each road, a neighbor is maintained by RSU and only two lists of neighbors are maintained by an OBU for the directions of forward and backward. This study has assumed that a GPS is provided for each vehicle to gain the information of the position. A "Hello" message is periodically broadcasted by each node in the VANETs. This beacon comprises of ID of the node, time stamp, and the location. At the time that a "Hello" beacon is received by a node, the digital street map is checked by the node and then the information of the neighbors is updated for the list of the neighbors of a node.

6.4. Comparison of Broadcasting Protocols in VANETs. In the previous section, a variety of broadcasting protocols for dissemination of information in vehicular ad hoc networks have been reviewed. A classification of these protocols is illustrated in Table 1.

TABLE 1: Comparison of broadcasting protocol in VANETs.

Existing protocol	Network scenario	V2V/V2I	Node selection parameter	Mechanism for network fragmentation
IVG	Highway	V2V	Distance	Periodic broadcast
DRG	Highway	V2V	Distance	Periodic broadcast
DV-CAST	Highway	V2V	Distance	Store carry forward
MobiCast	Highway	V2V	Distance	Store carry forward
SRD	Highway	V2V	Distance Direction	Store carry forward
EAEP	Highway	V2V	Random	Epidemic
UV-CAST	Urban	V2V	Distance, angle	Store carry forward
EDB	Urban	V2I	Distance	Repeater
Streetcast	Urban	V2I	Distance	RSU
POCA	Both	V2V	Distance	Store carry forward
DECA	Both	V2V	Density information around node	Store carry forward
Ack-PBSM	Both	V2V	Connected dominating set	Store carry forward

TABLE 2: Strength and weakness of broadcasting protocol in VANETs.

Existing protocol	Strength	Weakness
IVG	(1) Mitigates broadcast storm problem (2) Efficient in fragmented network (3) Distributed algorithm	(1) Just functions in highway scenario (2) Requires accurate GPS information (3) Periodically rebroadcasts safety message
DRG	(1) Distributed algorithm (2) Mitigates broadcast storm problem	(1) Data dissemination may be slow because of ZoF (2) Mitigates network fragmentation periodically which causes high reception overhead
DV-CAST	(1) Distributed framework (2) Mitigates broadcast storm problem and network fragmentation in a single framework (3) Efficient for safety emergency applications	(1) Just functions in straight highways (2) Highly dependable on position and direction information of vehicles gathered from GPS
Mobicast	(1) Mitigates broadcast storm problem (2) Efficient in fragmented network	(1) Just functions in highway scenario (2) Complicated mechanism to select vehicles in Zof and ZoR
SRD	(1) Simplicity (2) Mitigates broadcast storm problem and fragmented network problem simultaneously	(1) Just functions in highway scenario (2) Not reliable for safety messages
EAEP	(1) No beacon exchange (2) Mitigates broadcast storm problem	(1) Just functions in highway scenario (2) Assumes end to end connection between vehicles
UV-CAST	(1) Mitigates broadcast storm problem and network fragmentation (2) Considers two different levels for communication range which is more realistic assumption	(1) High complexity because of gift-wrapping algorithm (2) Just functions in urban scenario (3) Assigns task of store carry forward to different vehicles
EDB	Receiver based decision	(1) Just functions in highway scenario (2) Fixed antenna direction with beam width of about 30 degree
Streetcast	By utilizing digital map, streetcast is a fast and accurate broadcast protocol	No specific method for fragmented network condition
POCA	(1) Eliminates broadcast storm problem and network fragmentation (2) Functions in different network scenarios such as highway and urban	(1) Utilizes 2-hop neighbor information (2) Very high reception overhead
DECA	(1) Functions in different network scenarios such as highway and urban (2) Mitigates broadcast storm problem and network fragmentation problem	(1) Selects relay vehicle based on random waiting time (2) Requires knowledge of 2-hop neighbors.
Ack-PBSM	Functions in different network scenarios such as highway and urban	(1) Data dissemination speed may be slow because of using CDs (2) Not efficient for safety emergency messages

All of the protocols discussed assume homogeneous communication range and bidirectional link. The reduction of redundant broadcast is done through the distance between sender and relay node. Although there are already different broadcasting protocols for VANETs, most of them can function just in a specific network scenario such as highway or only in urban. There is a great need to have an ultimate protocol with no assumption about network scenarios, which can function in different road topology such as highway and urban.

Table 2 shows strength and weaknesses of these broadcasting protocols in VANETs.

7. Conclusion

In this paper, an extensive literature review for connected and fragmented vehicular ad hoc network is discussed. The main parts of this paper include an overview of VANETs and DSRC standard, VANETs characteristics, architecture, applications, and their requirements. The current research challenges of VANETs broadcasting protocols are focused on issues such as broadcast storm problem and network fragmentation. The disseminating protocols of VANETs and their approaches, strengths, and weaknesses to handle these problems are discussed.
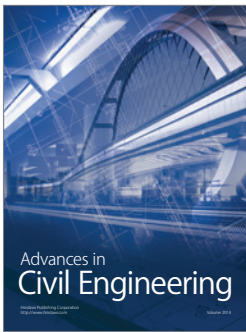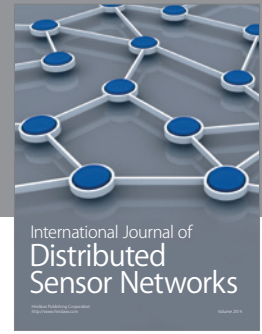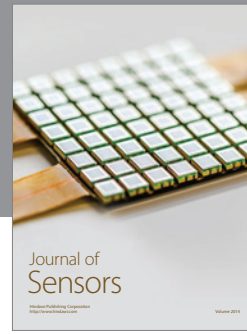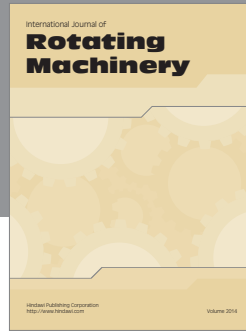
Conflict of Interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

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