A Review of Various VANET Data Dissemination Protocols

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Abstract

VANETs (Vehicular Ad hoc Networks) are upcoming wireless network environment for Intelligent Transportation Systems (ITS). Most VANET applications are built upon the data push communication model, where information is disseminated to a set of vehicles. The diversity of the VANET applications and their potential communication protocols needs a systematic literature survey. In this paper VANET characteristics and challenges are discussed. Application based various broadcasting data dissemination protocols are surveyed separately and their fundamental characteristics are revealed. In the end a tabular comparison of all the protocols is given.

Keywords: *VANET, Protocols, Data Dissemination*

1. Introduction

The advent of ad hoc wireless networking is arguably one of the most significant developments in wireless networking and telecommunications in the last decade [1,2]. While the research into this area has started as a result of the immediate needs of the Department of Defense (DoD) in the USA for military combat operations in hostile territories, the application areas have since grown tremendously and have expanded to include the synergistic area of sensor networks as well. Nevertheless, it is fair to say that the bulk of the research in ad hoc networks has stayed focused on military applications with few commercial applications that seemed viable in the foreseeable future. This picture has changed dramatically in the last 5 years or so with the advent of the automobile industry showing interest in the future of Vehicular Ad Hoc Networks, mainly for safety applications. Indeed, this is probably the biggest new commercial application of ad hoc networks with real and concrete applications (such as safety) driving the march of the underlying technology.

With the development in the field of wireless communications, ITS applications are developed based on car-to-car communication standards such as Wireless Access in Vehicular Environments (WAVE) and Dedicated Short Range Communications (DSRC). WAVE and DSRC standards are defined in IEEE 1609.1-4 and 802.11p respectively. The fact that FCC has allocated dedicated 75 MHz frequency spectrum in the range 5.85 GHz to 5.925 GHz to be used only for Vehicle to Vehicle (V2V) and Vehicle to Infrastructure (V2I) communication. This new application clearly indicates that this is much more than a trend and it is destined to grow into a commercially viable technology [3, 4].

When one reflects upon the current state of affairs, it is probably not very surprising that we are witnessing an exponentially growing interest in this area, both from academia and automobile industry: after all, with 60–100 embedded sensors with their corresponding microprocessors, the contemporary cars are the best mobile computing platforms that one could dream for. They are highly mobile and they have a tremendous amount of embedded computing power. While the car industry, for safety applications, has embraced this new research area and technology as its own, at the present juncture the number of potential applications have quickly expanded beyond safety and now includes other types of applications as well.

VANETs can be considered as a subset or special case of Mobile Ad Hoc Networks (MANETs) which have been studied extensively in the literature [1]. The research in this area is relatively new and it essentially spans the last decade. While some significant progress has been made, it is fair to say that several key research and development problems remain open [5]. In terms of V2V communications, the use of both radio (very high frequency (i.e., VHF), micro, and millimeter waves) and infrared waves have been reported in experimental V2V systems [6-8]. While infrared and millimeter waves can support only line-of-sight communications, VHF and microwaves can support broadcast communications as well. VHF can provide long links but at low speed and for this reason the mainstream mode of communications is to use microwaves.

Using vehicular communications, drivers can be well informed of vital traffic information such as treacherous road conditions and accident sites by communicating amongst vehicles and/or with the roadside infrastructure. With the large information of traffic conditions, vehicles will have better knowledge and it is reasonable that the problem of road accidents can be alleviated. Vehicular communications also facilitate traffic monitoring and management (e.g., vehicle platooning [9]) in order to raise traffic flow capacity and improve vehicle fuel economy.

2. Architecture of Vehicular Networking

A Vehicular Ad hoc Network (VANET) is a kind of wireless ad hoc network to provide communications among vehicles and nearby roadside equipments. VANET consists of vehicles with on-board sensors and roadside units (RSUs) deployed along highways/sidewalks, which provides communications between vehicle-to-vehicle (V2V) and communications between vehicles-to-infrastructure (V2I). Figure 1 gives an illustration of the architecture of VANET. Vehicles V1, V2, and V3 have access to a roadside infrastructure, which has limited coverage.

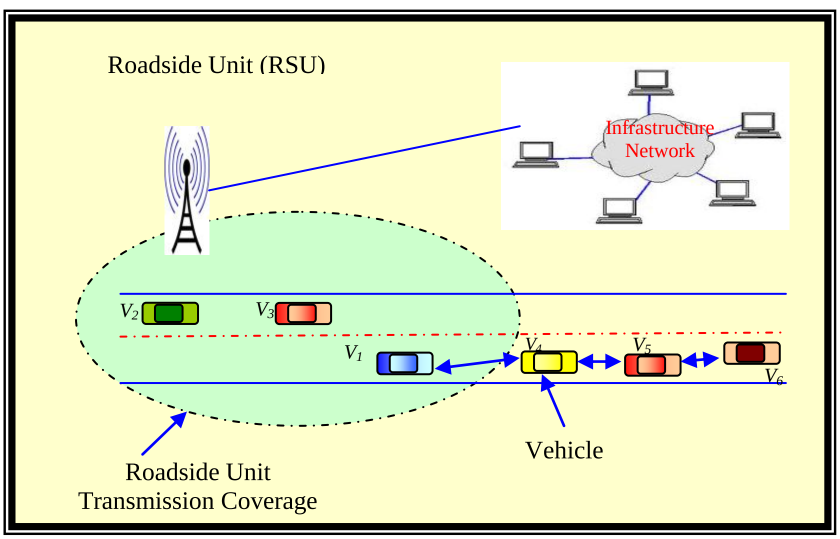

Figure 1. Vehicular Ad Hoc Network Architecture [10]

These vehicles can obtain information from the roadside base station. However, vehicles V4, V5, and V6 have no communications with the fixed infrastructure. For instance, Vehicle V6 will have to rely upon information from vehicle V5, which in turn has obtained information that has passed through vehicles V1 and V4.

Each vehicle communicates with nearby vehicles in a highly dynamic ad hoc networking environment via V2V communications. Traffic-related information can be exchanged through periodic beaconing to allow drivers to be aware of surrounding traffic conditions. Event driven messages can be generated in case of emergency and disseminated to the vehicles in the zone of relevance (ZOR) [11]. Infotainment applications such as gaming, file downloading requiring peer-to-peer communications can also be supported through V2V communications. In the presence of RSUs, Internet access can also be made possible for the occupants in the vehicle. Information from a remote data server can be delivered to a vehicle through the Internet backbone, and vice versa. RSU provides larger communication service area and can provide infotainment services such as advertisements, parking lot availability, and automatic tolling with ease.

The Federal Communications Commission (FCC) in the United States has allocated 75 MHz of licensed spectrum from 5.850 GHz to 5.925 GHz as the dedicated short range communication (DSRC) band for ITSs to enable communication-based safety and infotainment services [14]. In Europe, different frequency bands are used for vehicular communications, for instance, unlicensed frequency band at 2010–2020 MHz is used in Fleetnet [12].

Recently, the European Telecommunications Standards Institute (ETSI) has also allocated a radio spectrum of 30 MHz at 5.9 GHz for ITSs. To improve quality-of-service (QoS) and spectrum utilization, multiple channels are expected to be employed in vehicular communications. Location information of vehicles is generally available through global positioning system (GPS). End-to-end paths can then be recognized via location-aware V2V and/or V2I transmission for information delivery. In near future, this emerging vehicular networking paradigm is expected to provide variety of automotive applications, ranging from collision warning/avoidance to road traffic monitoring to seamless inter-vehicle video streaming.

3. Applications and Use Cases for VANET

Applications of VANET can be classified into three major categories 1) Safety applications, 2) Traffic monitoring and management applications and 3) Infotainment applications.

1) Safety Applications

Safety applications are the most important applications type that is primarily focused on to decrease the chances of road accidents and the loss of life of the occupants of vehicles [13, 15, 19]. A large number of accidents that occur in all parts of the world are associated with vehicle collisions. This class of applications primarily provides active road safety to avoid collisions by assisting the drivers with timely information. Information is shared between vehicles and road side units which is further used to predict vehicle collisions. Safety information can be represented with vehicle’s speed, position, intersection position and distance heading. Moreover, hazardous locations, such as slippery sections or potholes on roads can be easily located using the exchange of information between the vehicles and the road side units. Few use cases of safety applications are given below [19–26]: -

- **Curve Speed Warning:** In this use case, a combination of GPS and digital maps are used to judge threat levels for a driver approaching a curve too quickly. If the driver enters a curve at a high speed and will not be able to drive through the curve safely, he will be warned automatically with a message. Acoustic as well as visual symbols may be used to warn the driver. The signal may directly appear on the instrument panel or in the navigation system.
- **Traffic Signal Violation Warning:** This use case is designed to send a warning message to a driver when it detects that the vehicle is in risk of running the traffic signal. The decision to send a massage is made on the basis of traffic signal status and timing and the vehicle's speed and position. The road surface and weather conditions are some other factors that are considered in such situations. This traffic violation information is further broadcasted by the RSU to all other vehicles in the neighborhood.
- **Emergency Electronic Brake Lights:** In this use case, the driver is alerted with a message when a preceding vehicle makes a severe braking maneuver. This alert notification is sent using the cooperation of other vehicles and/or road side units. Surrounding vehicles that receive this warning message will act accordingly if the event is relevant or ignore if it is not concerned with them.
- **Pre-Crash Sensing / Warning:** In this use case, it is assumed that a crash is unavoidable and will take place. The system is designed in a way to reduce the effect of an accident using equipments like actuators, air bags, motorized seat belt pre-tensioners and extensible bumpers. Also the driver is warned, brakes are pre-charged, seat belts are retracted, excess slack is removed and automatically applying partial or full braking to minimize the crash severity. Vehicles and the available RSUs also share information periodically to predict collisions. The exchanged information includes detailed position data and vehicle size.
- **Collision Risk Warning:** In this system, vehicles and RSU detect chances of collision between multiple vehicles that are not able to communicate amongst themselves. The system will collect data about vehicles that are coming from opposite direction and are approaching towards the intersection, using sensors or DSRC communications. The collected information is further disseminated to inform vehicles that are going to take turn. One way to implement such system is by collecting the data continuously, and when there is a vehicle with its turn signal on, the system will send a message to that vehicle about the traffic traveling in the opposite direction of the vehicle. The other way is to have an in-vehicle system that sends a request to be notified about the traffic in the opposite direction when the turn signal is activated. The system will then collects data about the traffic in the opposite direction and sends a message to the vehicle that requested the information. In both ways, the driver will be informed and warned about the traffic coming in the opposite direction.
- **Lane Change Assistance / Warning:** In this application, electronic systems incorporated in vehicle monitor the position of a vehicle within a roadway lane and warn a driver if it is unsafe to change lanes or merge into a line of traffic at any instant. These systems are backward looking and assist drivers who are intentionally changing lanes by detecting

vehicles in the driver's blind spot. Therefore, the risk of lateral collisions for vehicles is reduced by accomplishing a lane change with blind spot.

- **Stop Sign Movements Assistance:** In this system both V2V and V2I communications are used. This system is designed in way to avoid accidents at stop sign intersections. Data is collected by sensors or DSRC communications that is further used to inform the driver when it is unsafe to pass through an intersection. Moreover it also warns drivers if there is any traffic coming through the intersection at the same time.
- **Control Loss Warning:** In this use case the system is intended to enable the driver of a vehicle to generate and broadcast a message to all surrounding vehicles in case of control-loss. Upon receiving such information, the nearby vehicles decide the relevance of the event and provide a warning to the drivers, if appropriate.

2) Traffic Monitoring and Management Applications

This class of application mainly focuses on improving the vehicle traffic flow, traffic coordination and traffic assistance. It provides updated local information, maps and relevant messages bounded in space and/or time. Traffic monitoring and management applications can be further categorized into two classes known as Speed management applications and Co-operative navigation applications [21].

- **Speed Management Applications:** The aim of speed management applications is to assist the driver in managing the speed of his/her vehicle. The driving is made smoother and it avoids unnecessary stopping. The examples of this type of application are regulatory/contextual speed limit notifications and green light optimal speed advisory.
- **Co-operative Navigation Applications:** This type of application is intended to increase the efficiency of vehicular traffic by managing the navigation. The vehicles navigate through cooperation among themselves and through cooperation between vehicles and RSUs. Few examples of co-operative navigation are traffic information and recommended itinerary provisioning, co-operative adaptive cruise control and platooning.

3) Infotainment Applications

Infotainment applications offer convenience and comfort to drivers and passengers. The gist of infotainment applications intend to provide all kind of messages that offer entertainment and useful messages to the driver and passenger. Locating the nearest coffee shop, cinema, mall, fuel station which offers the best price in that area, or available parking spot are the few examples of infotainment applications. Infotainment applications can be further subdivided into two categories 1) Co-operative local applications and 2) Global Internet Applications [19, 22, 26].

- **Co-operative Local Applications:** The services provided by co-operative local applications focus on infotainment that can be obtained locally such as point of interest notification, local electronic commerce and media downloading.
- **Global Internet Applications:** In this class of applications the focus is on data that can be obtained from global Internet services. Few examples of global internet applications are community’s services, which includes insurance and financial services, fleet management and parking zone management, and ITS station life cycle, which focuses on software and data updates.

4. Characteristics of VANET

In addition to the similarities to ad hoc networks, VANETs possess unique network characteristics that distinguish it from other kinds of ad hoc networks and influence research in this area. Few important characteristics of VANETs are as follows:

- **Somewhat predictable but Highly Dynamic Topology:** In VANET, the movement of each vehicle is restricted to roads patterns. With the knowledge of roadway geometry, the mobility pattern of vehicles can be predicted to a certain extent. Although mobility pattern of vehicles can be predicted in VANET but vehicles move at a very high speed and hence the topology of VANETs changes frequently.
- **Frequent Network Disconnection:** Due to the highly dynamic topology, the link connectivity in VANETs also changes frequently. Especially when the density of vehicles is low, the chancees of network disconnection are quite high.
- **Mobility Modeling and Predication:** Due to the high vehicle movement and dynamic topology, mobility models and predication play key role in designing the data dissemination approaches for VANETs.
- **Geographical Type of Communication:** In contrast to other mobile wireless networks that only use either unicast or multicast way for communication where the end points are defined by ID or group ID, the VANETs also supports a different type of communication that deals with packet forwarding based on geographical area.
- **Different Communication Environments:** Generally VANET operates in two typical communication environments known as highway scenarios and city scenarios. In highway traffic scenarios, the communication environment is comparatively simpler and straightforward (e.g., constrained one-dimensional movement), while in city traffic conditions it becomes quite complex.
- **Adequate Storage and Energy:** In VANET, nodes have sufficient amount of energy and computing power including both processing and storage because nodes are vehicles in VANET instead of small handheld devices in other networks.
- **Hard Delay Constraints:** Some of the applications in VANET do not require high data rates but has hard delay constraints.
- **Interaction with On-Board Sensors:** Each node in VANET is equipped with on-board sensors and GPS to provide information that can be further used to form communication links and data dissemination.

5. Challenges in VANET

VANET supports diverse range of on-road applications and hence requires efficient and effective radio resource management strategies. This includes QoS control, capacity enhancement, interference control, call admission control (CAC), bandwidth reservation, packet loss reduction, packet scheduling and fairness assurance. In VANET, vehicles (or nodes) are generally organized in an ad hoc fashion; still VANET differs from traditional mobile ad hoc network (MANET) in terms of the network architecture, user mobility pattern, energy constraint, and real-life application scenarios [27]. Therefore, existing approaches designed for MANETs are ineffective and/or inefficient and cannot be directly applied in VANET. To accomplish various applications in a vehicular environment, new and effective strategies are required to be tailored specifically meant for VANET. Following are the key research challenges in VANET: -

- **Frequent Link Disconnections**: As discussed in the previous section that unlike nodes in MANETs, vehicles are highly mobile and generally travel at higher speeds, especially on highways (i.e., over 100 km/hr) and thus changes the topology of a network. It causes intermittent communication links between a source and a destination [28]. Moreover, the network resources allocated to vehicles go in vain due to frequent link disconnections. Suppose a sender is travelling at 110 km/hr and its corresponding receiver is travelling at 120 km/hr in the identical direction, and the communication range is 300 m [14]. The communication can only last for a minute between both the vehicles. The situation is more worsen if the vehicles travelling in opposite directions, a communication link can only be there for less than 5s. Consequently, analysis of connectivity and management of mobility-aware resource are important.
- **Highly Dynamic Spatio–Temporal Traffic Conditions**: The density of vehicles in VANET varies from very small as in highway scenario to very large as in a traffic jam in city scenario. The flow of vehicular traffic is also dynamic, primarily contingent upon the time of the day [29]. To deal with varying spatio–temporal traffic conditions is important yet challenging. Specifically, in the beginning phase of deployment of VANET, it is anticipated that only few vehicles are VANET-enabled. Participation by only few such vehicles possibly aggravates the problem of frequent network fragmentation, thereby the effective diameter of a VANET is restricted. Other prime concerns are wireless channel impairments such as slow fading and fast fading that causes dynamic traffic variations. Fast fading is exhibited by vehicular environment where vehicle density is low, and vehicles can travel at a high speed. On the other hand, Slow fading, is experienced in a situations where vehicle density is high such as in a traffic jam. In both spatio and temporal domains, channel conditions vary greatly. Therefore, the design of adaptive channel access protocols with resistance to channel impairments is of prime concern.
- **Heterogeneity of Applications**: VANET provides a wide range of road safety and infotainment applications. Generally, road safety applications need low latency and high reliability. On the other hand, infotainment applications require better throughput, low packet loss, higher resource utilization. In light of heterogeneous information services, channel access protocols and network resource allocation strategies should be adaptive to ensure efficient, orderly, and fair communications among all the vehicles on road [26]. In VANETs, it is clear that safety-related (infotainment) messages should be assigned high (low) priority. Devising an effective and efficient communication approach to guarantee vehicle safety yet offer quality infotainment services in a highly dynamic vehicular environment is necessary.
- **Information Dissemination:** Disseminating traffic information in VANET is a critical problem. In contrast to other networks such as Internet where data is typically unicasted, the traffic information has a nature which requires broadcasting [30]. Traffic information is destined for public interest, and not only for an individual. Therefore, disseminating the traffic information using broadcasting scheme is more suitable as compared to a routing approach that employs unicasting. Broadcasting scheme has the advantage that a vehicle does not require the destination address and the route to a particular destination. As a result it reduces the various difficulties in VANET such as complexity of route discovery, address resolution, and topology management.

Above mentioned VANET- specific technical challenges cannot be completely solved alone by simply broadcasting data. It should be noted that a holistic solution is to be followed that governs the dissemination of information in an efficient manner while considering the various features of different layers in the VANET protocol stack.

6. Data Dissemination Techniques in VANET

Many of the problems are resolved by the process of effective data dissemination. There are many parameters that have to be kept under consideration during disseminating the data like network size, vehicle’s speed, patchy and intermittent connectivity between mobile nodes. In addition to these difficulties, there is one more problem which can severely affect the entire process i.e. latency requirements. Consequently, content information has to be discovered quickly and distributed among nodes [30]. According to the literature, there are many methods of information delivery in VANET. Generally speaking, following are the distinguished approaches for data dissemination:

- **Opportunistic Data Dissemination:** Information is retrieved from infrastructure / vehicles as the target vehicle encounters them.
- **Vehicle-Assisted Data Dissemination:** All vehicles carry information along with them and deliver it either to the infrastructure RSU or to other vehicles when they are encountered. In order to disseminate the information, mobility is also involved apart from the wireless transmissions.
- **Cooperative Data Dissemination:** Partial information can be downloaded by the vehicles that can be shared later to obtain the complete information. This method is mainly appropriate for content dissemination.

1.6 Organization of the Paper

The rest of the paper is organized as follows. Single-hop broadcasting and multi-hop broadcasting protocols are reviewed in Section 2. Section 3 discusses the data dissemination using network coding technique and explains the proposed approach. In Section 4, we discuss the performance evaluation of the proposed work with other protocols. Summary and discussion on open issues are provided in Section 5.

7. Broadcasting Protocols in VANET

During the last few years, a lot of broadcasting protocols for VANETs have been reported in the literature. They can be generally classified into two main categories according to the spreading of information packets in the network. These categories are [31-43]:

- **Single-hop Broadcasting:** In single-hop broadcasting, information packets are not flooded by vehicles. Instead, when a packet is received by a vehicle, information is kept in the vehicle’s on-board database. Periodically, every vehicle selects some of the records stored in its database to broadcast. Hence, in single-hop broadcasting, each vehicle carries the traffic information with itself as it travels, and this information is transferred to all other vehicles in its one-hop neighborhood in the next broadcast cycles. Ultimately, vehicle’s mobility is involved in spreading the information in single-hop broadcasting protocol.
- **Multi-hop Broadcasting:** On the other hand, in multi-hop broadcasting strategy, a packet is spread in a network by the way of flooding. In general, when a sender vehicle

broadcasts an information packet, a number of vehicles within the vicinity of the sender will become the next relay vehicles by rebroadcasting the packet further in the network. Similarly, after a relay vehicle (node) rebroadcasts the packet, some of the vehicles in its vicinity will become the next relay nodes and perform the task of forwarding the packet further. As a result, the information packet is able to propagate from the sender to the other distant vehicles.

7.1 Single Hop Broadcasting Protocols

In single hop broadcasting, vehicle periodically disseminates some of the information in its database to the other vehicles in the network. Broadcast interval and information are the two choices that need to be considered while designing the broadcast protocol for VANET. To keep the most up-to-date information without redundancy, the broadcast interval must be set appropriately. It should not be too long and not too short. Apart from this, important and relevant information should only be selected to broadcast. Single-hop broadcasting protocols can be further divided into following two categories: -

7.1.1 Fixed Interval Based Single Hop Broadcasting Protocols: Fixed broadcast interval protocols focuses only on the selection and aggregation of information. TrafficInfo [44] is an example of fixed broadcast interval protocol in which every vehicle is equipped with a global positioning system (GPS) and digital road map and periodically broadcasts the traffic information stored in its database. A particular type of traffic information reported is the travel times on the road segments. During broadcasting process each vehicle stores its own travel time and time taken by other vehicles during travelling into the database. Although single-hop broadcasting scheme is inefficient in broadcasting all the records from database but, TrafficInfo uses the bandwidth efficiently and broadcasts only the most relevant top k information from the database. The relevance of the information is determined by a ranking algorithm, which is based on the current location of the vehicle and the current time.

TrafficView is another single-hop fixed interval broadcasting scheme [45] designed for enabling an exchange of traffic information among vehicles. Speed and position are two information types that are exchanged among the vehicles. In this scheme, when a vehicle receives a broadcasted packet, it first stores the information in its database. The information is then rebroadcasted in the next broadcast cycle. However, instead of broadcasting all stored record from the database, only a single record is broadcasted after aggregating the multiple records. Ratio-based and the cost-based are the two algorithms that are used for aggregation. In the ratio-based algorithm, a road is divided into small regions, and an aggregation ratio is assigned to each region according to the importance of the region and the level of accuracy required for that region. While in cost-based algorithm, cost can be regarded as the loss of accuracy incurred from combining the records. Simulation shows that although the cost-based algorithm yields better accuracy, the ratio-based algorithm gives more flexibility.

7.1.2 Adaptive Interval Based Single Hop Broadcasting Protocols: In adaptive broadcast interval protocols, an adjustment of broadcast intervals is also taken into consideration. Collision Ratio Control Protocol (CRCP) [46] uses adaptive broadcast interval in which each vehicle disseminates the traffic information periodically. The traffic information in this case is the location, speed, and road ID and is measured at every second. This protocol employs a mechanism for dynamically changing the broadcast interval based on the number of packet collisions. Basically, the protocol aims at keeping the collision ratio at a targeted level regardless of the vehicle density. Intuitively, the number of packet collisions increases with an increase in network density. Apart from adaptive broadcast interval mechanism, three methods Random Selection (RS), Vicinity Priority Selection (VPS), and Vicinity Priority Selection with Queries (VPSQ) are proposed for selecting the data to be disseminated.

Abiding Geocast protocol [47] is another example of adaptive broadcast interval protocol which was designed to disseminate safety messages within a useful area where these messages are still relevant. In this scheme, a vehicle which detects an emergency situation first starts broadcasting a warning packet. Packet specifies the area where the warning is still relevant. When another vehicle receives the warning message, it will act as a relay node and keep broadcasting the warning packet as long as it is still traveling in the concerned area. Each vehicle adjusts its rebroadcast interval dynamically in order to reduce the number of redundant warning packets. The rebroadcast interval is decided by the transmission range, speed, and the relative distance between the emergency site and the vehicle.

Segment-oriented Data Abstraction and Dissemination (SODAD) protocol [48] also uses adaptive broadcast interval in which roads are divided into segments of predefined length. Each vehicle collects the data by sensing the information itself and from the reports of other vehicles. Each vehicle adaptively adjusts its broadcast interval to reduce the redundancy. Information received from other vehicles is characterized in two ways (i) provocation and (ii) mollification. A provocation event is an event that reduces the time until next broadcast, whereas a mollification event is defined as an event that increases the time until next broadcast. When a vehicle receives a packet, it determines whether it is a provocation or a mollification event by assigning a weight to the received packet. A weight is calculated from the discrepancy between the received data and those in the vehicle's knowledge database. The weight will be high if the received information is newer than the stored information. Based on the packet weight, node determines whether a provocation or mollification event has occurred by comparing it with a threshold. The time for next rebroadcast is increased or decreased depending on the weight.

7.2 Multi Hop Broadcasting Protocols

As mentioned earlier, in multi-hop broadcasting [50-63], flooding is used for packet propagation in the network. However, a pure flooding is inefficient because it lacks scalability and there is lot of packet collision. Redundancy increases as the network becomes denser and wastes the channel bandwidth which in turn reduces the network scalability. In addition, packet collision is another critical problem because multiple vehicles in the same region may rebroadcast the packet at the same time. This is called as a broadcast storm problem [49]. Multi-hop broadcasting can be further divided into following three categories: -

7.2.1 Delay Based Multi Hop Broadcasting Protocols: In a delay-based multi-hop broadcasting scheme, different waiting time before rebroadcasting the packet is assigned to each receiving vehicle. Fundamentally, the vehicle having a shortest waiting time gets the highest priority to rebroadcast the packet. In addition, redundancy is avoided by the other vehicles by aborting their waiting process once they know that the packet has already been rebroadcasted. While different delays are assigned to each vehicle in delay-based broadcasting protocols, a different rebroadcast probability is assigned to each vehicle in a probabilistic-based protocol.

Urban Multi-hop Broadcast (UMB) protocol [50] is a delay based multi-hop broadcasting protocol designed to solve the broadcast storm, the hidden terminal, and the reliability problems in multi-hop broadcasting. UMB divides a road inside the transmission range of a transmitter into smaller segments, and it gives the rebroadcast priority to the vehicles that belong to the farthest segment. UMB uses two types of packet forwarding: (i) directional broadcast and (ii) intersection broadcast. UMB is inefficient because, next rebroadcast vehicle has to wait the longest before being able to transmit the clear to broadcast (CTB) packet. This is due to the longest black-burst duration is assigned to the next rebroadcast vehicle.

Smart Broadcast (SB) [51] was proposed to improve the shortcomings of UMB protocol. In SB when a source vehicle has a packet to send, it transmits a request to broadcast (RTB) packet containing its location and other information such as packet propagation direction and contention window size. Also, all vehicles in the range of the source that receive the RTB packet determine the “sector” in which they belong by comparing their locations with that of the source vehicle. Next, all vehicles that receive the RTB packet choose a contention delay based on the sector that it resides.

Efficient Directional Broadcast (EDB) protocol [52] is another delay-based multi-hop broadcast protocol that works somewhat similar to UMB and SB protocols. However, it does not use RTB and CTB control packets. EDB also exploits the use of directional antennas. In particular, it is proposed that each vehicle is equipped with two directional antennas, each with 30-degree beam width. Similar to UMB protocol, EDB also uses two types of packet forwarding, namely directional broadcast on the road segment and directional broadcast at the intersection.

Slotted 1-Persistence Broadcasting protocol [53] is a packet forwarding approach similar to those of the other delay-based multi-hop broadcasting protocols, in which the vehicles that are farther away from the transmitter will get the rebroadcast priority. In this protocol, when a vehicle receives a packet, it rebroadcasts the packet according to an assigned time slot, where the time slot is a function of distance between the vehicle and the transmitter. In particular, each vehicle computes the time slot in which it will rebroadcast the packet based on the following equation: -

$$T_{S_{ij}} = S_{ij} * \tau \qquad \text{---(1)}$$

Where τ is an estimated one-hop propagation and medium access delay, and S_{ij} is the assigned slot number.

Reliable Broadcasting of Life Safety Messages (RBLSM) [54] is also a class of delay based multi-hop broadcasting in which as soon as a node receives a packet from source, it determines the waiting time for rebroadcasting the packet. In contrast to the other conventional strategies where the rebroadcast priority is given to the farthest vehicle, in RBLSM the priority is given to the vehicle nearest to the transmitter. The reason behind choosing the nearest vehicle as the next rebroadcaster is that, it is considered to be more reliable than the other vehicles that are at far away distance from the transmitter. It is assumed that nearer vehicle has better received signal strength. This protocol also uses the concept of RTB and CTB control packets. Performance evaluation is done via simulation with only single hop latency. Link-based Distributed Multi-hop Broadcast (LDMB) is a similar protocol which assigns the waiting delay based on a link quality as proposed in [55].

Fastest-Vehicle [56] is another multihop routing protocol. It uses speed information of each vehicle for message transfer and distance of the selected vehicle from the destination vehicle. On the basis of speed v of the vehicles and distance s of the vehicles from the destination, the time t for each vehicle within the transmission range is calculated. The vehicle with the least time is selected as the next hop for data dissemination.

7.2.2 Probability Based Multi Hop Broadcasting Protocols: In probabilistic-based broadcasting approach, each vehicle rebroadcasts a packet according to the assigned probability. Since only few vehicles will rebroadcast the packet, redundancy and packet collisions are reduced. The third category of multi-hop broadcasting is network coding which has caught attention in the field of ad hoc wireless communications.

Weighted p-Persistence protocol [53] is a probability based broadcasting scheme in which a vehicle that receives a packet for the first time computes its own rebroadcasting probability based on its distance from the transmitter. The distance can be computed by comparing its current position with the position of the transmitter specified in the packet. In particular, the rebroadcast probability is computed from the following equation: -

$$P_{ij} = \frac{D_{ij}}{R} \qquad \text{---(2)}$$

where D_{ij} represents the distance between transmitter i and vehicle j, and R is the transmission range of transmitter i. On the basis of above equation, vehicles that are farther away from the transmitter will get higher rebroadcast probabilities. However, vehicle density is not taken into consideration in this probability assignment function. Hence, in the dense network, the number of rebroadcast packets can still be large.

There is another protocol named Optimized Adaptive Probabilistic Broadcast (OAPB) protocol [57], in which number of neighbors' i.e. local vehicle density is also taken into consideration while determining the forwarding probability. Each vehicle exchanges HELLO packets periodically to select an appropriate forwarding probability. In particular, when a vehicle receives a packet, it computes its own forwarding probability based on the following equation: -

$$\bar{\phi} = \frac{P_1 + P_2 + P_3}{3} \qquad \text{---(3)}$$

where P_1, P_2,and P_3 are functions of the number of one-hop neighbors, the number of two-hop neighbors, and a set of two hop neighbors that can only be reached through a particular one-hop neighbor [57].

AutoCast protocol [58] is similar to OAPB in which the rebroadcast probability is determined from the number of neighbors around the vehicle. However, it uses a different probability function to obtain rebroadcast probability: -

$$p = \frac{2}{N_h * 0.4} \qquad \text{---(4)}$$

where N_h is the number of one-hop neighbors. According to the above probability assignment function, the rebroadcast probability decreases as the number of neighbors increases. Evidently, this function can only work when the number of neighbors, N_h is greater than or equal to *5*. However, it is not clearly specified in [58] how the probability is assigned in the cases where $N_h < 5$.

7.2.3 Network Coding Based Multi Hop Broadcasting Protocols: Network coding is a new way of information dissemination which can be applied to a deterministic broadcast approaches, resulting in significant reductions in the number of transmissions in the network and hence yields a much higher throughput than the traditional way of transmission.

COPE introduced in [59] is based on the principle of network coding. Although COPE is a unicast routing protocol, but it is a foundation for many multi hop routing protocols. The

COPE was intended to realize the benefits of network coding beyond the simple duplex flows. The COPE was based on three key techniques: (i) opportunistic listening, (ii) opportunistic coding, and (iii) neighbor state learning. Opportunistic listening simply allows nodes to take the advantage of wireless broadcast medium by snooping all data packets. Each overheard packet will be stored in the node's buffer for a limited time period. These packets will later be used for network coding when the opportunity presents. Opportunistic coding, defines some basic rules for a node to encode and transmit a packet. Basically, a node should ensure that its next hop neighbor has enough information to decode the encoded packet that has been transmitted. Usually, a node will be able to correctly decode a packet i from an encoded packet created from packets $p_1,p_2,...,p_n$ if it has $n - 1$ of these packets. Thus, learning what packets its neighbors are having is crucial, and this is achieved with a periodic broadcast of reception reports. Hence, every node periodically announces packets that are stored in its reception buffer to all its neighbors.

CODEB is another network coding-based broadcasting protocol introduced in [60]. It extends the concepts and techniques proposed in COPE to cover broadcasting scenarios in wireless ad hoc networks. It uses opportunistic listening, where each and every node snoops all packets overheard by it. In addition, each node periodically broadcasts the list of its one-hop neighbors. This allows all nodes to build a list of its two-hop neighbors, which will further be used to construct a broadcasting backbone. Moreover, CODEB relies on opportunistic coding, in which coding opportunities to transmit coded packets is determined. CODEB also pointed out that opportunistic coding for broadcast is somewhat different from coding for unicast. In broadcasting all the neighbors of the node must receive the packet where as in unicasting, only the intended next hop node receives a given packet. Hence broadcasting increases the level of complexity as all nodes that receives packet must be able to decode.

Efficient Broadcasting Using Network Coding and Directional Antennas (EBCD) is a network coding-based broadcasting protocol which gains the benefit of both network coding and directional antennas [61]. EBCD similar to CODEB also determines a subset of neighboring nodes that can perform forwarding task deterministically. Although, Dynamic Directional Connected Dominating Set (DDCDS) algorithm is used by EBCD. As a result, a directional virtual network backbone is constructed by DDCDS where each node determines both its forwarding status as well as the outgoing edges (antenna sectors) in which the packets can be transmitted. EBCD and CODEB also have one more difference that, in EBCD, network coding is applied in each sector of the directional antennas around the node whereas in CODEB, network coding is applied in omni-directional. EBCD shows significant improvement with directional antennas and network coding in terms of number of transmissions, over to other schemes.

DifCode is also a network coding-based broadcasting protocol. Its goal was to reduce the number of transmissions required to flood packets in wireless ad hoc network [62]. Similar to CODEB, DifCode also chooses the next forwarding nodes deterministically. However, DifCode uses a selection algorithm based on multi-point relay (MPR) [63]. MPR of a node is the list of its one-hop neighbors that covers its two-hop neighborhood. In DifCode, nodes can encodes and broadcasts only those packets that are received from those nodes that select it as their MPR. DifCode and CODEB also differ by their opportunistic coding techniques. In CODEB, all neighbors of a transmitter decode the received packets immediately and hence limit coding opportunities. On the other hand DifCode relaxed this constrain by allowing nodes to buffer packets that are not immediately decodable. Specifically, all nodes will maintain buffers for keeping three different types of packets: (i) successfully decoded packets, (ii) not immediately decodable packets, and (iii) packets that need to be encoded and broadcasted further. Simulation results also show that DifCode also results in lower redundancy rate than the probabilistic broadcasting protocols.

8. Conclusion

We have performed an extensive survey of various inter-vehicle communication applications and systematically classified them. This organizational approach permitted us to identify the communication requirements unique to each application type and focus on the most important protocol design issues that the developers are facing. We carefully reviewed these issues and illuminated the options using protocol examples taken from the past decade of research on IVC. Various applications were highlighted and used to analyze a representative set of protocols, which were classified by their architectural as well as relevance. Additional details on selected protocols appropriate to each of the defined application types are presented. We have also discussed some important strengths and weaknesses of current research. Table 1 compares each protocol with another on different parameters. We also considered the future evolution of inter-vehicle applications into complete transportation systems that support multiple protocols operating under a common management framework.

Table 1. Comparison of Various Broadcasting Data Dissemination Protocol in VANET

S. No.	Name of Protocol	Hoping Level	Basis	Simulation Platform Used	Metrics Used for Evaluation
1.	TrafficInfo	Single-Hop	Fixed Broadcast Interval	STRAW / SWANS	Packet Delivery Ratio
2.	TrafficView	Single-Hop	Fixed Broadcast Interval	NS-2	Propagation Distance
3.	Collision Ratio Control Protocol (CRCP)	Single-Hop	Adaptive Broadcast Interval	NETSTREAM	Packet Drop Ratio
4.	Abiding Geocast	Single-Hop	Adaptive Broadcast Interval	OMNeT++	Broadcast Overhead
5.	Segment-Oriented Data Abstraction and Dissemination (SODAD)	Single-Hop	Adaptive Broadcast Interval	NS-2	Packet Drop Ratio, End to End Delay
6.	Urban Multi-hop Broadcast (UMB)	Multi-Hop	Delay	MATLAB, CSIM	Load Generated Per Broadcast Packet, Packet Delivery Ratio, Dissemination Speed
7.	Smart Broadcast (SB)	Multi-Hop	Delay	MATLAB	One Hop Progress, Rebroadcast Latency, Dissemination Speed
8.	Efficient Directional Broadcast (EDB)	Multi-Hop	Delay	Proprietary	Forward Node Ratio, Packet Delivery Ratio

9.	Slotted 1-Persistence Broadcasting	Multi-Hop	Delay	OPNET	Link Load, Reception Rate, Packet Drop Ratio, No. of Hop Propagated, End to End Delay
10.	Reliable Method for Disseminating Safety Information (RMDSI)	Multi-Hop	Delay	NS-2	Packet Delivery Ratio, End to End Delay
11.	Multi-hop Vehicular Broadcast (MHVB)	Multi-Hop	Delay	NS-2	Packet Delivery Ratio, Packet Drop Ratio
12.	Reliable Broadcasting of Life Safety Messages (RBLSM)	Multi-Hop	Delay	MATLAB	Dissemination Speed
13.	Vehicle-density-based Emergency Broadcasting (VDEB)	Multi-Hop	Delay	NS-2	Redundancy Rate, End to End Delay
14.	Fastest-Vehicle Multi-hop Routing	Multi-hop	Delay	NCTUns	Packet Collision and Drop Ratio
15.	Link Based Distributed Multi-hop Broadcast (LDMB)	Multi-Hop	Delay	Not Specified	Packet Delivery Ratio, End to End Delay
16.	Weighted p-Persistence	Multi-Hop	Probabilistic	OPNET	Link Load, Reception Rate, Packet Drop Ratio, No. of Hop Propagated, End to End Delay
17.	Optimized Adaptive Probabilistic Broadcast (OAPB)	Multi-Hop	Probabilistic	NS-2	Broadcast Overhead, Packet Delivery Ratio, End to End Delay
18.	AutoCast	Multi-Hop	Probabilistic	NS-2	Packet Delivery Ratio, Dissemination Speed
19.	Irresponsible Forwarding (IF)	Multi-Hop	Probabilistic	MATLAB, NS-2	Redundancy Rate, Reception Rate, Saved Rebroadcast, End to End Delay
20.	CODEB	Multi-Hop	Network Coding	NS-2	Packet Delivery Ratio
21.	Efficient Broadcasting Using Network Coding and Directional Antennas (EBCD)	Multi-Hop	Network Coding	NS-2	Redundancy Rate, Packet Delivery Ratio
22.	DifCode	Multi-Hop	Network Coding	OPNET	Redundancy Rate

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