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A SURVEY ON TOPOLOGY-BASED MESSAGE BROADCAST SCHEMES IN VEHICULAR NETWORKS

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Abstract. *Vehicular ad-hoc networks (VANETs) are subclass of mobile ad-hoc networks (MANETs). They have been the most promising research field and development for the last few years. VANETs use vehicles as mobile nodes to provide communication among nearby vehicles and between vehicles and nearby roadside equipment. VANETs come with several challenging characteristics, such as dynamic and potentially large scale network topology, high mobility and intermittent connectivity of vehicular nodes, and broadcasting as the predominant communication to disseminate the safety messages. When a traffic accident happens, the safety message should be broadcasted to all vehicles in the area exposed to potential hazard. Recently, there have been a significant number of broadcasting protocols for VANETs reported in the literature. In this survey paper we provide an overview of topology-based broadcasting protocols and associated requirements, along with challenges and their proposed current and past major solutions. In addition, classification and comparison of topology-based broadcasting protocols are described from their pros and cons. Featured solutions in this domain are categorized and discussed.*

Key words: *VANET, ITS, safety message dissemination, WAVE, topology-based dissemination, eSBR, eMDR.*

1. Introduction

In the last few years with the enhancement and development of vehicle industry and wireless communication technology Vehicular Ad-hoc Networks (VANET) are becoming one of the most promising research fields. VANETs are wireless communication networks that support cooperative driving among communicating vehicles on the road. Vehicles perform as communication nodes or relays, forming highly dynamic vehicular networks together with other nearby vehicles or with nearby roadside equipment. Especially, the

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vehicles (network nodes) in VANETs are limited to road topology while moving, and vehicles move along known paths, often in a predictable manner. If the road information is available, it is possible to predict the future position of a vehicle or get information about various risk traffic events and accidents [1]. Vehicles in the VANET network are equipped with various wireless communication devices which can directly communicate without infrastructure and centralized control. Vehicles can have significant sensing, computing and communication capabilities and all those facts allow data to be quickly delivered to applications. Intelligent transportation systems (ITS) can provide efficient solutions for road traffic problems such as driver assistant, safety transport applications or collision warning message detection by combining communication technology and information systems with the advanced mathematical models. VANET applications need a fast and reliable solution for data dissemination to provide precise and reliable services [2].

VANETs provide both Vehicle-to-Vehicle (V2V) and Vehicle-to-Infrastructure (V2I) communication. A vehicle can communicate to an infrastructure via Road Side Unit (RSU) or embedded On-Board Unit (OBU) devices. V2V communications are suited for active safety and real-time situation awareness as well as other applications based on wireless Inter-Vehicle Communication (IVC). V2I communication enables real-time traffic/weather updates and environmental sensing/monitoring for drivers. Fig. 1 shows a typical VANET traffic scenario [3].

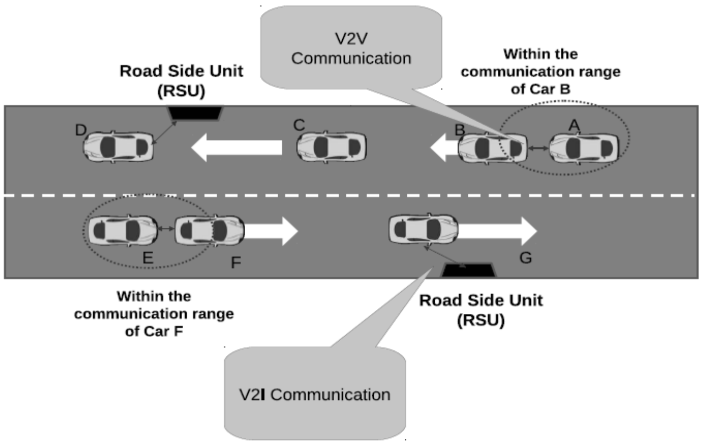

Fig. 1 Creating an ad-hoc network using vehicles (VANET)

Data or message dissemination refers to the process of spreading data or information over distributed wireless VANET networks. When the V2V working mode is used, the broadcast message frame is directly sent by the source to the vehicles in the radio-frequency (RF) range. Those exchanging messages which are disseminated to all or part of the vehicles come from infrastructure or from the vehicles themselves. Data exchange also requires implementation of network and transport mechanisms to disseminate the message in the whole VANET network. The message will be disseminated in a multi-hop fashion when the V2V communication is enabled, and will be broadcasted by all the RSU devices when

V2I communications are used instead. These messages can be flooded at a certain number of hops or in a given area depending on the VANET application purposes. The mobility of vehicles results in a dynamic scenario with considerable rate of link changes and very short lifetime for multi-hop paths [4].

Traffic safety by disseminating safety messages is one of the most important applications of VANETs. Safety applications can be more efficient if information from vehicle's embedded systems and sensors is exchanged between neighboring vehicles. As a result, a timely warning may help the driver to avoid an emergency stop, traffic collisions or road hazard situations. Safety message broadcasting is considered delay sensitive to overcome the constraints of driver reaction time for taking proper actions towards potential incidents ahead [5].

During the last decade, there have been a number of message broadcasting protocols or schemes for VANETs. A major difference between these types of protocols is in the way that the messages are spread in the VANET network. We can classify them according to the different characteristics and techniques they use to determine whether a vehicle is allowed to rebroadcast a message (i.e. distance-based, topology-based, store-and-forward techniques, probabilistic based). In this paper, we introduce some of the most relevant broadcast topology-based schemes proposed to disseminate messages in case of accident, or to advertise any critical situation on the road.

This paper is organized as follows. Section 2 describes basic current standards and application categories in VANETs. Section 3 presents dissemination schemes and technologies and section 4 gives comparative classification of topology-based schemes and presents representative examples. Concluding remarks are given in the last section.

2. STANDARDS AND APPLICATIONS OF VANET NETWORKS

2.1. Layers architecture and standards in VANET networks

The different standards and frequencies weighted the implementation of ITS systems since each country has its own VANET specifications. Dedicated Short-Range Communication (DSRC) was used in Europe to explain the protocols used in Electronic Toll Collection (ETC), but nowadays it is used around the world. The DSRC construct of RSU and OBU is placed on the side of the road and in vehicles. The DSRC was assigned a frequency range of 75 MHz (5.850-5.925 GHz) for VANETs from the Federal Telecommunications Standards Committee (FTSC). As shown in Fig. 2 [6], channels of DSRC are divided into one Control Channel (CCH) and six Service Channels (SCH), which have 10MHz bandwidth each. The channel number of 178 (CH 178) is used as a safety message and alarm service, and other SCH are used as non-safety service channels. When using bandwidth of 10 MHz, the DSRC supports a data rate of 3-27 Mbps, and when using the maximum bandwidth (20 MHz), the DSRC supports data rate of up to 54 Mbps. In addition, DSRC supports Orthogonal Frequency Division Multiplexing (OFDM) technology for support orthogonal channels between vehicles. IEEE 1609 Working Group (WG) proposed a family of network standards for vehicular networks called Wireless Access in the Vehicular Environment (WAVE).

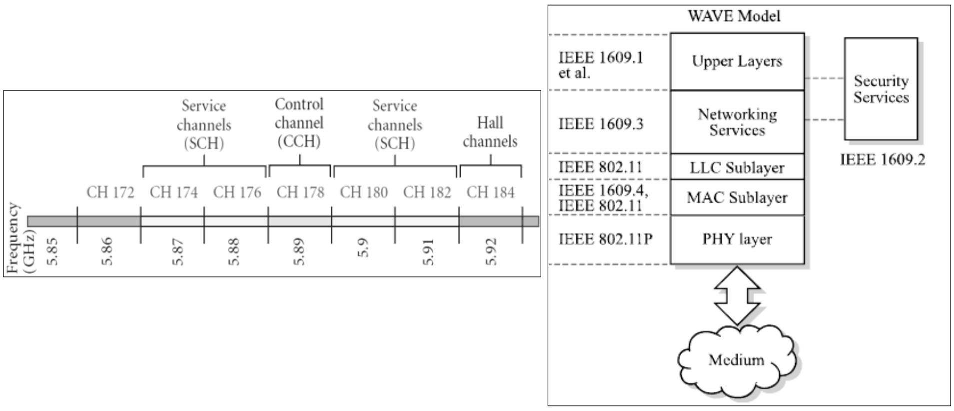

Fig. 2 WAVE channel arrangement (left) and simplified WAVE categories suite (right)

The WAVE network stack uses a modified version of IEEE 802.11a for its Medium Access Control (MAC) known as IEEE 802.11p. The protocol architecture defined by IEEE is shown in Fig. 2. The WAVE is divided into four categories:

- IEEE 1609.1 is the standard for Resource Manager and deals with resources such as OBUs, RSUs and Access Points (APs). Also provides access for applications to the rest of the architecture
- IEEE 1609.2 defines security, secure message formatting, processing, and message exchange
- IEEE 1609. 3 defines routing and transport services and provides an alternative for IPv6
- IEEE 1609.4 defines how the multiple channels specified in the DSRC standard should be used

2.2. Application categories in VANET networks

There are many research studies focused on classifying vehicular applications [7, 8]. Motivated by the need to minimize the continuously increasing number of traffic accidents, the majority of applications proposed in VANETs are designed to improve active safety in driving. However, messages exchanged between vehicles can be used for other purposes, such as improving driving, passenger comfort and traffic efficiency.

Applications of VANETs can be basically classified into three major categories: 1) Safety applications 2) Traffic management and monitoring applications and 3) Comfort or infotainment applications. The schematic representation of the VANETs applications classification is shown in Fig. 3. This classification is based on the European Telecommunications Standards Institute (ETSI) approach and partly modified to integrate a larger number of vehicular applications [7].

Safety applications are the most important and primarily focused on reducing the chances of road accidents and helping human drivers to maintain safe driving in various hazardous conditions. Safety messages can include the following warnings to avoid vehicle accidents: curve speed, traffic signal violation, pre-crash sensing, collision risk, emergency electronic brake lights, lane change assistance, control loss etc. [9]. VANET safety category is responsible for awareness, warning and assistance services and is mapped to Active Road Safety class of services through Cooperative Awareness (CA), Cooperative Driver Assistance (CDA) and Road Hazard and Collision Warning (RHCW) applications (Fig. 3). Vehicular CA applications help drivers to be aware of other vehicles or situations and provide information about the surrounding environment using internal and external sources. CDA systems support drivers in their task of driving a vehicle (cruise control, adaptive steering and lane change assistance). RHCW applications provide information about close collisions due to hazardous road conditions, obstacles, and erratic drivers. Crash detection systems (CDS) act in the pre-crash and post-crash phases. Most CDS rely on radars, sensors, or cameras to detect an imminent crash.

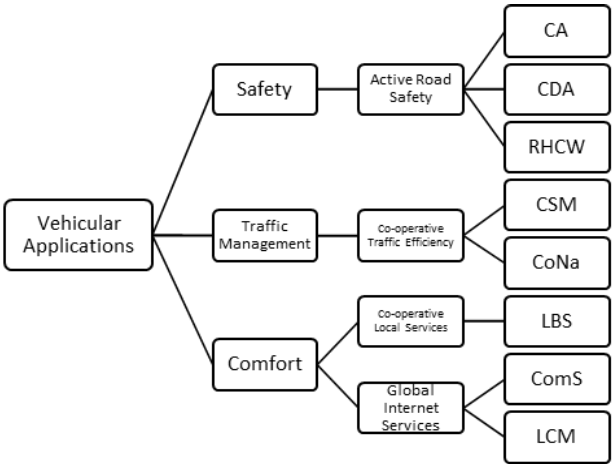

Fig. 3 Vehicular applications classification [7]

Traffic management and monitoring applications are time sensitive as safety applications. This class of application mainly focuses on traffic monitoring and management. Traffic control applications can include the following: traffic light control, speed management, or co-operative navigation. These applications are intended to increase smooth traffic flow, safety, and comfort of driving, especially in the urban areas. Traffic Management category is mapped to the Convenience/Cooperative Traffic Efficiency class, as shown in Fig. 3. Cooperative Traffic Efficiency provides two applications: Cooperative Speed Management (CSM) and Cooperative Navigation (CoNa). With the CoNa application, a vehicle gets advised for the optimal route and gets assisted in navigation. CSM applications are responsible for speed limit notifications and the traffic light optimal speed advisory.

The comfort category of VANET applications are intended to improve passenger comfort. This category is mapped to Cooperative local services and Global Internet services class. The Cooperative local services class provides Location-Based Services (LBS) application. Global Internet Services class provides Communities Services (ComS) and ITS station Life Cycle Management (LCM) applications. ComS applications are: insurance and financial services, fleet management services and cargo monitoring and tracking. LCM applications provide remote vehicle personalization/diagnostics and vehicle and RSU data calibration services.

3. Data Dissemination Schemes in VANET Networks

The most suitable communication mechanism to disseminate safety messages in vehicular networks is broadcasting. Flooding is the simplest broadcast scheme to deliver safety messages to all vehicles in their radio transmission range. However, flooding introduces the broadcast storm problems and redundant message retransmission. Broadcast storm is a well-known problem in ad hoc networks and was mentioned first in [10]. In basic flooding (also called blind flooding) a vehicular node transmits a message, which is received by all neighboring nodes that are within the transmission range. Each node determines if it has transmitted the message before. If not, then the message is retransmitted and disseminated throughout the network. Blind flooding terminates when all nodes have received and transmitted the message being broadcast at least once. Since each node forwards the message, it leads to an important redundancy which depends on the network density. A vehicular node will receive as many messages as it has neighbors in its radio range.

Generally, broadcasting dissemination schemes for VANETs can be divided into two main categories: multi-hop and single-hop broadcasting. In multi-hop broadcasting, a message propagates through the network by way of flooding. When a source vehicle broadcasts an information packet, some of the vehicles within the vicinity of the source will become the next relay vehicles and perform a relaying task by rebroadcasting the message further. As a result, the information message will be able to propagate from the source to the other distant vehicles. In single-hop broadcasting, vehicles do not flood the messages. Instead, when a vehicle receives a message, it keeps the information in its OBU database. Each vehicle selects some of the records in its database to broadcast. With single-hop broadcasting, each vehicle will carry the traffic information with itself as it travels, and this information will be transferred to other vehicles in its one-hop neighborhood in the next broadcast cycles.

VANET message dissemination techniques are strongly affected by:

- the signal attenuation due to the distance between sender and receiver vehicle (especially in low vehicular density areas)
- the effect of obstacles in signal transmission (very usual in urban areas due to buildings)
- the instantaneous vehicle density

To overcome the broadcast storm problem, a lot of selective retransmission protocols are proposed. In modern VANETs most dissemination schemes mitigate the broadcast storm problem by inhibiting certain vehicles from rebroadcasting using different parameters, reducing message redundancy, channel contention, and message collisions. There are various classifications of the broadcast dissemination schemes presented in literature [11, 12]. Vehicular dissemination schemes can be classified according to the different characteristics and techniques they use to determine whether a vehicle is allowed to rebroadcast a message (flooding, distance, topology, probability etc.). In this section, we mainly focus on V2V communications and present an overview of the existing broadcasting schemes and achieving message dissemination. Fig. 4 shows the proposed classification of the dissemination scheme.

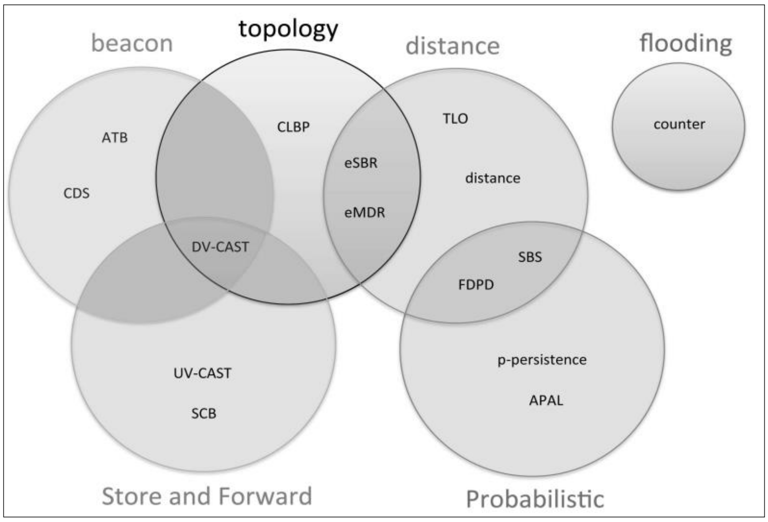

Fig. 4 Classification of the VANET broadcast schemes according to the dissemination policy adopted [13]

Simple flooding: This is the simplest broadcast scheme where vehicles blindly rebroadcast every message. In dense networks, a flooding scheme results in the redundant rebroadcasts, medium contention and packet collision. In sparse network vehicles may face network disconnections when the transmission range cannot reach other vehicles farther in the direction of interest. In such scenarios, protocols should also incorporate a store-carry-forward mechanism. The counter-based dissemination (i.e. a limited flooding) is part of simple flooding scheme. This scheme uses a threshold C and a counter c to keep track of the number of times the broadcast message is received. Whenever $c \geq C$, rebroadcast is inhibited.

Beacon-based scheme: Beacons are messages sent by vehicles with information regarding their positions, speed, etc. When using safety applications, these periodic messages have lower priority than warning messages, and so they are not propagated by other vehicles. The information contained by these messages could be used to improve the knowledge about the surrounding area of each vehicle, taking decisions accordingly. The CCH channel interval for beacon dissemination can be adaptively adjusted based on both the current local traffic dynamics and the networking situation. Numerical results show that the proposed scheme can significantly improve the beacon dissemination performance especially in disturbance scenarios [14]. There are several proposed schemes in this category such as ATB, CDS, and DV-CAST and all of them use the received beacons to determine whether to rebroadcast a message.

Distance-based scheme: In this category vehicles use the relative distance between them to decide whether to rebroadcast a message. Each vehicle is equipped with a GPS device with which it is able to determine signal strength of a neighbor vehicle. When the distance between two vehicles is short, the additional coverage of the new rebroadcast is lower, and rebroadcasting the warning message is not recommended [15]. If distance is larger, the additional coverage will be larger, increasing the usefulness of messages forwarded. Several broadcast schemes fall into this category, such as TLO, SBS, eSBR, eMDR, FDPD, ODAM-C, MHVB etc.

Store and Forward based scheme*:* In this technique, a vehicle, after receiving a new warning message, stores it, and then it waits to rebroadcast the message based on a specific criteria which determines when the package should be sent. According to this technique, the vehicle usually waits to rebroadcast the message until a new neighbor is found, trying to maximize the performance, especially in sparse environments. Several proposed schemes belong to this category such as UV-CAST, SCB, and DV-CAST.

Probabilistic-based scheme: The probability-based schemes use a predefined fixed probability to select the relay vehicle that rebroadcasts the messages. These protocols might work in dense networks when multiple vehicles have similar neighbor coverage, but will not have a significant effect in sparse networks. Most of the schemes that fall in this category make use of the Gaussian or the uniform distribution to associate a probability to each message or vehicle. Several broadcast schemes fall into this category such as p-persistance, FDPD, SBS, APAL, OAPB, REAR etc.

Topology-based scheme: In next section we describe some of the topology-based broadcasting schemes. These VANET topology-based broadcast schemes use information regarding topology to improve the message dissemination process.

4. Topology-Based Broadcast Schemes in VANETs

Topology-based broadcasting schemes use network topology information such as node density, position and link connectivity between nodes to perform packet forwarding. An important factor here is the information about urban roadmaps. The information about the roadmap topology is used to improve the dissemination performance. Only vehicles placed at convenient locations are allowed to forward messages. Based on the kind of the road that vehicles pass on, the traffic patterns vary. The road topology also puts a strict constrais on the movement of the vehicle. While moving around, the vehicle 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 [16]. There is intense necessity to have an appropriate broadcast protocol with no assumption about network scenarios, which can function in different road topology such as highway and urban. There are several topology-based proposed broadcast schemes, such as eSBR, eMDR, JSF, NJL, DV-CAST, CLBP, and VDF.

4.1. eSBR broadcast scheme

The enhanced Street Broadcast Reduction (eSBR) broadcast scheme uses benefits of the information provided by built-in GPS positioning systems and roadmaps. Vehicles are only allowed to rebroadcast messages if they are located far away from their source ($>d_{min}$), or if the vehicles are located in different streets. When the additional coverage area is wide enough, vehicles will rebroadcast the received warning message. When the coverage area is low, vehicles will rebroadcast warning messages only if they are in a different road. This scheme uses information about the roadmap to avoid blind areas due the presence of urban obstacles blocking the RF signal. In most cases, buildings will absorb RF waves at this frequency, making communication only possible when the vehicles are in line-of-sight. Details about sSBR scheme considered in [13, 17].

A eSBR pseudocode of the sending warning/beacon message process by vehicle node is shown in Fig. 5. In this broadcast scheme vehicles operate in two modes – warning and normal. Warning mode vehicles inform other vehicles about their status by sending warning messages periodically (every T_w seconds) and these messages have the highest priority at the MAC layer (AC3). Normal mode vehicles send beacons with specific information (such as their positions, speed, etc.) periodically every T_b seconds, and allow the diffusion of the warning messages. These periodic beacon messages have lower priority (AC1) than warning messages and are not propagated by other vehicles. With consider to warning messages, each vehicle is only allowed to propagate them once for each sequence number (older messages are dropped).

```
Pw=AC3;   //set the highest priority
Pb=AC1;   //set default priority
ID=0;     //initialize sequence number of messages
while (1) do
if (vehicle_i is in warning mode) then
      create message m;
      set m.priority=Pw;
      set m.seq_num=ID++;
      broadcast warning message (m);
      sleep (Tw);
else
      create message m;
      set m.priority=Pb;
      broadcast beacon (m);
      sleep (Tb);
--------------------------------------------------------------------------------
```

P_w – priority of the warning messages
P_b – priority of the normal messages
T_w – interval between two consecutive warning messages
T_b – interval between two consecutive normal messages
ID – sequence number of message
$vehicle_i$ – each vehicle in the urban environment
m – each message sent or received by each vehicle
beacon – normal message generated by an normal vehicle

Fig. 5 eSBR pseudocode of the sending warning message [17]

The broadcasting process begins when $vehicle_i$ starts the broadcast of a message *m* to all its neighbors. When another vehicle receives *m* for the first time, it rebroadcasts it by further relaying *m* to its neighbors. Every vehicle repeats send warning or beacon messages periodically with different periods T_w and T_b. When a new message *m* is received, the vehicle tests whether *m* has already been received. Each vehicle maintains a list of message IDs. If message *m* is received for the first time (its ID has not been previously stored in the list), a message ID is inserted in the list. The message will be rebroadcasted to the surrounding vehicles only when the distance *d* between sender and receiver is higher than a distance threshold *D*, or the receiver is in a different street than the sender. Hence, warnings can be rebroadcasted to vehicles which are traveling on other streets, overcoming the RF signal interference due to the presence of buildings.

In [17] simulation results show that eSBR scheme outperforms other solutions in high density urban scenarios, yielding a lower percentage of blind vehicles while drastically mitigating the broadcast storm problem.

4.2 eMDR broadcast scheme

The enhanced Message Dissemination for Roadmaps (eMDR) scheme represents an improvement of the eSBR. This solution increases the efficiency of the broadcasting by avoiding to forward the same message multiple times if nearby vehicles are located in different streets. Vehicles use the information about the junctions of the roadmap. Just only the closest vehicle to the geographic center of the junction (according to the GPS system) is allowed to forward the received messages. Fig. 6 shows the eMDR working algorithm, where V_s and V_r are the sender/receiver vehicle, j is a junction of the roadmap, d represents a geographical distance function, d_{min} is the minimum rebroadcast distance and th_j is the threshold representing a junction's influence range. This scheme aims at reducing the number of broadcasted messages while maintaining a high percentage of the informed vehicles [13].

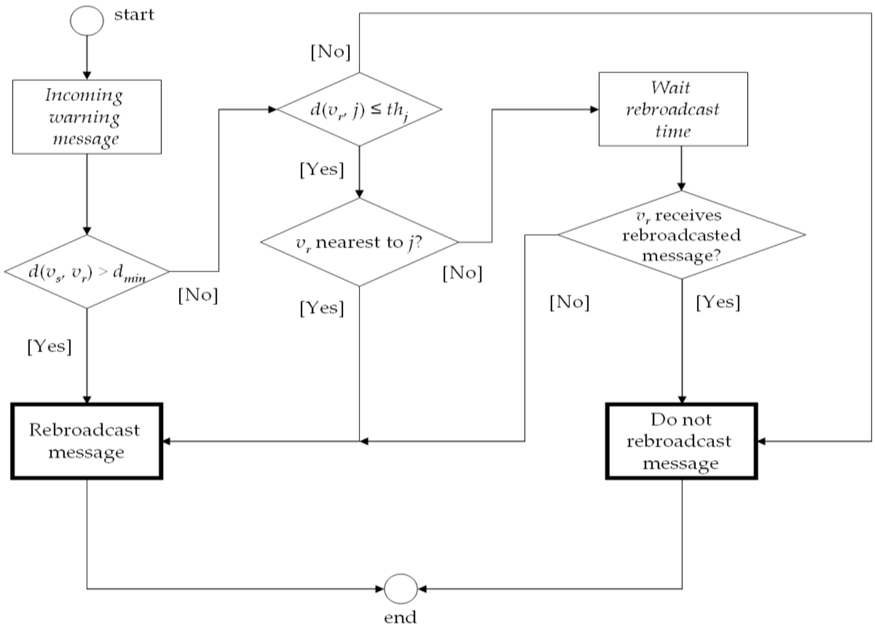

Fig. 6 eMDR broadcasting algorithm flowchart [13]

4.3. DV-CAST broadcast scheme

In particular, Distributed Vehicular BroadCAST (DV-CAST) is a broadcast protocol that uses only local connectivity information for handling broadcast messages. Each vehicle continuously monitors its local connectivity in order to determine which state it is operating in at the time of the packet arrival. Each vehicle has a GPS communication device and not every vehicle is a member of a specific VANET. This scheme uses connectivity of vehicles on a road to determine if the neighborhood is well connected, sparsely connected, or totally disconnected. The accuracy of the local topology information is an important factor that could cause the protocol to fail. The DV-CAST protocol breaks down the warning message forwarding once a duplicate is received from either direction. This protocol is based on the local information provided by one-hop neighbors via periodic hello messages. As shown in Fig. 7 this protocol based on local density of neighbor vehicles, their position, and their direction [18].

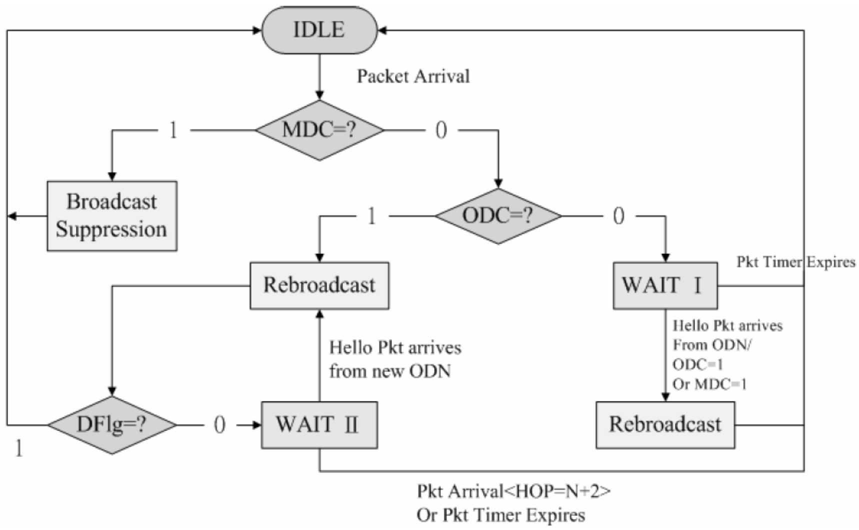

Fig. 7 DV-CAST broadcast decision tree flowchart [18]

There are four broadcast parameters in presented scheme:

- Destination Flag (DFlg) – determines whether it is the recipient of the message that is moving in the same direction as the source
- Message Direction Connectivity (MDC) – determines whether it is the last vehicle in the group/cluster
- Opposite Direction Connectivity (ODC) – determines whether it is connected to at least one vehicle in the opposite direction
- Opposite Direction Neighbor (ODN)

If *DFlg=1* vehicle should ignore any duplicate broadcast. If *DFlg=0* vehicle is a relay node. A vehicle is in "well-connected" neighborhood if it has at least one neighbor in the message forwarding direction (MDC=1). Each vehicle in group, except for the vehicle which is the last in the cluster (MDC=0), will have the following parameters (MDC=1, ODC=1/0, DFlg=1). A vehicle is operating in a sparse traffic regime if it is the last one in a cluster. The parameters for these vehicle should be set to (MDC=0, ODC=1, DFlg=0/1). A vehicle operating in a sparse traffic regime is a totally disconnected neighborhood if it has no neighbor in the message forwarding direction and is not connected anybody in the opposite direction (MDC=0, ODC=0, DFlg=1).

The DV-CAST protocol deals with extreme situations such as dense traffic conditions during rush hours and sparse traffic during certain hours of the day. This protocol mitigates the broadcast storm and the disconnected network problems simultaneously.

4.4. JSF broadcast scheme

Scenarios presenting very low traffic vehicle densities are often found in residential, rural, and peripheral urban traffic areas. In these traffic conditions the importance of the number of messages received per vehicle is lower. Because the number of vehicles is reduced the broadcasting schemes should focus on forwarding warning messages even when the probability of informing new vehicles is low. Schemes that can be used under very low vehicle densities conditions are flooding, counter-based or based on eSBR scheme.

The Junction Store and Forward (JSF) scheme is designed to exploit the road topology by considering that vehicles in junctions are in an optimal position to rebroadcast warning messages. Fig. 8 shows flowchart of the JSF broadcast scheme.

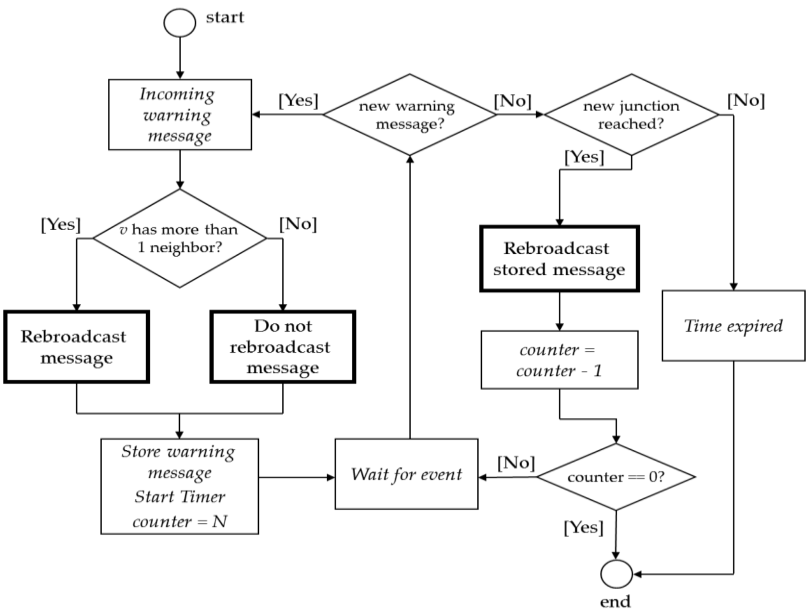

Fig. 8 JSF broadcast decision tree flowchart [20]

The vehicles located near junctions have a higher probability of reaching new vehicles within line-of-sight. According to [20], the vehicle uses the location provided by the integrated GPS system to determine if the vehicle is near a junction once the message is received and stored in OBU device. This scheme requires the presence of a neighbor list in each vehicle, built using the one-hop beacons periodically interchanged by the vehicles with information about their position and speed. After the reception of a new message, the vehicle checks the presence of additional neighbors apart from the sender of the message, hence avoiding sending useless messages in case there are no additional neighbors. A timer is used to dispose old stored messages. Vehicles using JSF scheme upon reaching a new junction forward the stored message a finite number of times *N* and the latter value is determined by the value of a counter updated whenever a new junction is reached.

If we look to the results in [20], the conclusion is that the JSF is able to increase the percentage of vehicles receiving messages and reduce the time required to inform 60% of the vehicles in the low density traffic scenario.

4.5. NJL broadcast scheme

In contrary with previous, situations with very high vehicle densities are very common in real urban environments. The vehicle density is enough to produce traffic jams, or significantly reduce the speed of vehicles. This effect leads to an increase of the number of vehicles sending messages and beacons in a specific area, generating a scenario for channel contention and message collisions. These situations require more restrictive dissemination schemes that allow reducing the number of messages sent in order to mitigate broadcast storms.

Fig. 9 shows the working flowchart of Nearest Junction Located (NJL) broadcasting scheme.

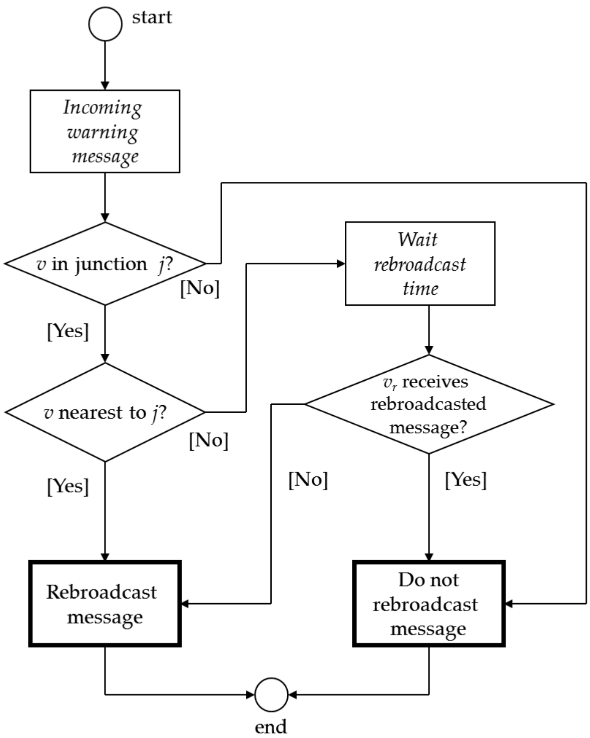

Fig. 9 NJL broadcast decision tree flowchart [20]

This scheme is based on the topology of the roadmap where the vehicles are located, allowing vehicles to rebroadcast a message only if they are the nearest vehicle to the geographical coordinates of any junction obtained from the integrated maps. This scheme also requires a neighbor list in each of the vehicles that allows determining the position of the surrounding vehicles. The NJL scheme is similar to the eMDR, although ignoring the distance between sender and receiver and it only focuses on the location of the receiving vehicle. Whenever a vehicle receives a message, it checks the position of its neighbors to determine whether it is the nearest to any junction of the road layout. The NJL scheme includes a mechanism to avoid failure due to the radio interface or GPS errors, waiting for a rebroadcast backoff time before forwarding the message whenever a better positioned vehicle is expected (right side part of the flowchart) [20].

Although the performance of this approach is not optimal in sparse environments, since it is very restrictive, it performs efficiently in high density scenarios where the dominant factor to improve the dissemination process is the position of the vehicles. It is obvious that achieving results similar to those obtained by the eMDR, while requiring only a fraction of the messages.

4.6. CLBP broadcast scheme

The Cross Layer Broadcast Protocol (CLBP) is a dissemination scheme that uses a metric based on physical channel conditions, geographical locations and moving velocities of vehicles to select an appropriate relaying vehicle. This scheme is a cross layer broadcast protocol for multihop message dissemination in inter-vehicle communication systems (IVCs). IVC enables vehicles to communicate with each other and exchange real-time safety related information such as traffic congestion notification, accident warning, road condition report etc. In [21] presented a CLBP for emergency message dissemination in a multi-hop IVC network, aiming to improve the transmission reliability and minimize the message redundancy in the meantime. This scheme also supports reliable transmissions exchanging Request to Send (RTS) and Clear to Send (CTS) frames. Each vehicle is equipped with a half-duplex transceiver and a GPS by which it can acquire its position information, moving velocity and moving direction. The vehicles are running on the highway that consists of several traffic lanes. To provide reliable transmissions of broadcast messages, broadcast RTS and CTS frames are exchanged before messages. The main objective of the proposed CLBP is to deliver the message to other vehicles as fast and reliable as possible. CLBP reduces the transmission delay, but it is only implemented for single direction environments, like highway scenarios.

4.7. VDF broadcast scheme

Vehicle Density-based Forwarding (VDF) adaptively chooses the forwarder according to the vehicle density to achieve the tradeoff between contention delay and forwarding hops. It selects a forwarder with an optimal hop distance according to vehicle density. Each vehicle utilizes the beacon message to inform its neighboring vehicles to detect vehicle density in the transmission range. The vehicle counts the number of vehicles in its transmission range through the counter of the received beacon message. Then vehicle calculates the vehicle density. The vehicle can calculate the distance from the current forwarder to itself. The waiting time is determined by the contention window in IEEE 802.11p MAC protocols to assign different waiting times from the reception to rebroadcasting of the message [19].

4.8. Overview of topology-based schemes

The overview and comparison of the previous described topology-based broadcasting protocols is summarized in Table 1. We analyzed the protocols in terms of various parameters such as the protocol category and its broadcast strategy aim, traffic density conditions and the percentage of vehicles receiving warning messages. As shown, most of the existing topology-based schemes (eSBR, eMDR, DV-CAST etc.) combine two different elements to improve performance (e.g. topology/store-and-forward techniques, beacons/topology, distance/probabilistic functions, etc.).

Table 1 Topology-based VANETs broadcast schemes (comparison summary)

Name of protocol	Preferred node selection algorithm	Broadcast strategy aims
eSBR [17]	Location, street map information of vehicle, distance between sender/receiver vehicle node	Reduce broadcast storm problem in real urban scenario with a complex set of streets and junctions; Simulation results show that eSBR outperforms other schemes in high density urban scenarios, yielding a lower percentage of blind vehicles
eMDR [13, 17]	Vehicles use the information about the junctions of the roadmap	Increase the efficiency of the broadcasting by avoiding multiple forwards of the same message if nearby vehicles are located in different streets; High percentage of the informed vehicles
DV-CAST [18]	Local information established by each vehicle via the use of periodic hello messages; Each vehicle monitors its local connectivity in order to determine which state it is operating	Mitigates broadcast storm problem and network fragmentation problem; Minimize number of forwarders, handle different traffic densities; Important factor that could cause the protocol to fail is the accuracy of the local topology information; Efficient for safety emergency applications.
VDF [19]	VDF selects a forwarder with an optimal hop distance according to vehicle density	VDF achieves the low broadcast delay and small broadcast count in multihop broadcast; VDF has better performance than the existing message broadcast protocols in two typical network applications including accident alert and online game.
JSF [20]	Vehicles located near junctions have a higher probability of reaching new vehicles within line-of-sight (LoS)	This scheme is the most effective one in low density scenarios; The differences in the number of messages received per vehicle are minimal; JSF is able to increase the percentage of vehicles receiving warning messages and reduce the time required to inform 60% of the vehicles
NJL [20]	This scheme is based on the topology of the roadmap where the vehicles are located	NJL performs efficiently in high density scenarios where the dominant factor is the position of the vehicles; Achieving results similar to those obtained by the eMDR
CLBP [21]	CLBP scheme uses a metric based on physical channel conditions, geographical locations and moving velocities of vehicles to select an appropriate relaying vehicle	CLBP is a cross layer broadcast protocol for multihop efficiently message dissemination in an IVC system; CLBP cannot only shorten the message transmission delay, but also deliver messages reliably with less resource consumption.

5. CONCLUSIONS

This paper firstly gives an overview of the broadcasting as an important communication mechanism to disseminate safety messages in VANETs. Generally, existing broadcast techniques can be categorized into several types: distance-based, topology-based, beacon-based, and probability-based. Secondly, it reviews existing performance modeling approaches for analyzing topology-based message dissemination in VANETs. Finally, main technical details and architecture of topology-based schemes are summarized. In previous papers [13, 17, 18, 19, 20] a topology-based message broadcast algorithm is evaluated in the context of many different parameters such as driving environments, road structure, mobility model, signal propagation, using maps etc. They are important factors influencing the performance such as percentage of informed vehicles, number of messages received per vehicle and message notification time. As compared to the other solutions, a topology-based schemes can eliminate many redundant rebroadcasts when the vehicle distribution is high or low dense.

In real high density traffic conditions eSBR scheme outperforms other schemes because the percentage of vehicles which receive warning messages increases to a greater extent. This is the less restrictive scheme and thus more suitable for high vehicle density conditions, but the main drawback is the high computational cost of calculating the additional coverage (informations provided by maps and built-in GPS devices). eMDR and eSBR schemes offer better results in scenarios where broadcast storms are not a problem, and the main objective is informing as many vehicles as soon as possible.

Under highly congested traffic conditions NJL proved to be the most efficient, but it is the most restrictive scheme and requires a very high density of vehicles to achieve an efficiency. The NJL scheme is the scheme that achieves the lowest value in the number of received messages and are recommended only for simple traffic roadmaps.

In very low density traffic conditions, JSF scheme that sends messages in an unlimited number of junctions provided better results than other versions that limit the number of junctions. JSF is able to significant reducing the warning notification time in low density traffic scenario. We can use combination of the topology information and store-forward based broadcasting scheme in the design of JSF, which is especially effective in complex traffic roadmaps.

There is no general framework that considers all of the influence factors for a performance evaluation of the topology-based dissemination protocols. This survey makes it possible to provide a variety of considerations that are required for designing a new class of VANET protocols.

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