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A Survey and Taxonomy of Broadcast Algorithms for Message Dissemination in Vehicular Ad Hoc Networks

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Abstract – Broadcasting in vehicular ad hoc networks (VANETs) has become an active area of research. VANET applications are inherently broadcast-oriented and require the underlying communication protocols to be reliable and scalable. On the other hand, the conventional broadcast mechanism may lead to the so called broadcast storm problem, a scenario in which there is a high level of contention and an excessive number of broadcast packets suffer from collision, which will affect heavily both the reliability and scalability of the protocols. Recently, numerous papers have proposed different methods to solve the broadcast storm problem in vehicular ad hoc networks. In this paper, we survey these message dissemination techniques and classify them into various groups. Also, we explain the different topologies and scenarios used in each of these groups.

Keywords *–intelligent transportation systems; vehicular ad hoc networks; safety message; vehicular safety applications; broadcast storm problem*

I. INTRODUCTION

Vehicular ad hoc networks (VANETs) provide communications among vehicles or between vehicles and fixed roadside equipment. VANETs are equipped with short to medium-range communication systems and their prospective applications include both safety and non-safety applications, which share the wireless channel with mobile applications. Non-safety applications, also called comfort applications, include traffic congestion avoidance, alternative route proposal, high speed tolling and mobile infotainment. Safety applications can further be categorized into periodic and event-driven applications. The first category has an informative nature, as messages are disseminated among vehicles regularly to inform them about their local parameters such as speed and position [1-2]. In the second category, event-driven applications, a safety message is broadcasted by a specific vehicle that experiences or detects a hazard or an unusual event. The safety message will propagate from a source outwards as far as possible in order to inform as many nodes in the network as possible about the situation. As a result, such messages have the highest priority. Due to the VANETs unique characteristics, such as scalability, high robustness expectations, strict delay requirements and security issues; the design of such a technology becomes an extraordinary challenge for the wireless research community [2].

Because of the shared wireless medium, broadcasting may lead to frequent contention and collisions in transmission among neighbouring nodes. This problem is sometimes referred to as the broadcast storm problem. While, solutions to alleviate this problem in mobile ad hoc networks (MANET) have been studied for many years [3-4], recently this subject has been considered in the VANET context. Broadcasting in VANET is very different from broadcasting in MANET due to several aspects such as network topology, mobility patterns and traffic patterns at different time of the day [5]. These differences show that conventional broadcasting algorithms in MANET are not appropriate for most vehicular broadcast applications. Therefore in the VANET concept, solutions have been presented based on different types of network traffic, such as dense, normal and sparse traffic. Additionally, other types of broadcasting algorithms are presented based on the topology of the roads. Despite the vast amount of research on different developed broadcasting algorithms in VANET, to our knowledge there are no distinct classifications of the proposed methods. In this paper, most of the recent broadcasting work is investigated and the message dissemination techniques are categorized into various groups.

The remainder of this article is organized as follows. First, we review all the challenges in the design of message broadcasting protocols in section II. Then, we introduce main evaluation metrics for broadcasting in VANETs in section III. Next, we present a classification of different broadcasting algorithms in VANETs in section IV. Discussion remarks for evaluating the different groups are presented in section V. Finally, section IV concludes this work.

II. CHALLENGES IN THE DESIGN OF BROADCASTING ALGORITHMS FOR SAFETY APPLICATIONS IN VANETS

Road safety applications require fast and reliable dissemination of the messages through the network. Therefore, all the requirements for optimal or suboptimal delivery of the messages should be considered. Some of the requirements are needed in any network; however some of them are application-specific. For example, reliability is needed for broadcasting of the safety messages in every topology, however, dissemination of the messages in some directions are application-dependent [6] [7]. During this survey, we found that broadcasting protocols should satisfy as many of the following requirements as possible as follows [8-14], [15-20]:

1. Reliability: a broadcasting protocol should have the capability to broadcast the messages to all the nodes in a reliable manner.
2. Robustness: a broadcasting protocol should be robust in all possible traffic conditions such, e.g., light traffic, moderate traffic and traffic jam.
3. Bandwidth efficiency: a designed protocol should impose a minimum overhead on the network.
4. Dissemination of the messages in the desired directions: a designed protocol should cover the network in all the required directions.

5. Imposing the minimum dissemination delay: message delay in the network should be minimized. This issue can be obtained by minimizing the one-hop delay or the number of relay hops.
6. Independency of centralized station: due to the decentralized nature of VANET, the broadcasting protocol should not be based upon a centralized station.
7. Fairness: all the nodes in the network should obtain access to the channel in a fair manner.
8. Collision robustness: There are two reasons why a collision may still occur: first, if there are many competing nodes, some of them may choose the same time slot. Second, the hidden node problem causes even more collisions at receivers that exist in the intersection of both senders since the MAC protocol of the sender is unaware of these nodes.
9. Selecting the proper transmission power: the PER (Packet Error Rate) generally decreases when increasing the transmission power of a specific message but if all nodes in a network increase their transmission power it may result in a highly saturated wireless channel with high probabilities of reception failure due to collisions.
10. Security: due to the message content importance, security considerations should be applied to broadcasting algorithms. On the other hand, users and auto-makers will not adopt a technology that allows vehicle movement to be tracked. Therefore, anonymity is crucial in VANET.

We will match these requirements into different algorithm groups at the end of this survey.

III. EVALUATION METRICS FOR SAFETY MESSAGE BROADCASTING

To evaluate the performance of the protocols, some evaluation metrics are needed. Some of the evaluation metrics are common in any wireless network; however there are specific metrics that are used to evaluate the broadcasting schemes in VANETs. In this section, all applicable evaluation metrics are introduced, in order to compare the different broadcasting algorithms. Some of themetrics have the same concept; therefore we can classify them in different groups as follows:

1. Delay:
   - 1-1 *Message delay* is calculated by averaging the delays of receiving a message by all the corresponding receivers. In some papers authors only consider time of receiving the message by the last receiver. It is referred to as “time to send” in [8]. In [9], authors calculate this parameter by multiplying the number of hops to one hop delay.
   - 1-2 *Channel occupancy time* is the total time that the channel is occupied while broadcasting an emergency message to vehicles in the system [6].
   - 1-3 *End to end delay* shows the delay to transmit a broadcast message from one node to the next one [6].

1-4 *Message delay of nth repetition* shows the delay to receive the nth repetition of a generated message at a specific distance away from the source [10].

1-5 *Medium access delay* is the time that a node waits for access to the wireless channel in order to transmit a head-of-the-line packet in the MAC sub-layer via the channel. This delay is only caused by the medium access competition and the fairness mechanism.

2. Delivery Success Percent:

2-1 *Packet loss rate* shows the packet loss rate during the broadcasting. Generally, it is defined as a ratio between dropped packets and generated packets in the network. Sometimes, authors calculate only dropped packets in the network as a number of collisions [8] or calculate probability of the message loss as the probability of message drop [11].

2-2 *Reception rate* represents the probability of message reception by a specific receiver at a particular distance away from the alert source.

2-3 *Probability of failed reception* represents the probability of not receiving the message by a specific receiver at a particular distance away from the alert source.

2-4 *Message reachability* is the ratio between the vehicles that receive the broadcast packet and the total number of vehicles in the network. Sometimes, this parameter is called the success percentage [7], delivery ratio [12] or packet penetration rate [9].

3. Network Load:

3-1 *Overhead* is the additional generated traffic of the protocol besides the main broadcasting messages.

3-2 *Efficiency* is in general the minimizing of the cost to reach a goal. In this research area, efficiency describes how efficiently a broadcasting method is performing with a limited amount of radio communication resources such as bandwidth, power and processing memory.

3-3 *Link load* measures the amount of broadcast traffic that is received at each node over a specific time. Normalized link load is the ratio between the link load and the worst case link load (using simple broadcast method).

3-4 *Load generated per broadcast packet* is the total number of bits transmitted when broadcasting a packet to the whole network.

4. Others:

   4-1 *Dissemination speed* represents how quickly information is disseminated by a broadcast protocol.

   4-2 *Uniformity* describes whether the message is uniformly disseminated from the source in all the required directions or not.

   4-3 *Hops* represent the number of nodes passed by a message from the source to the destination.

The main evaluation metrics introduced above are used in every broadcasting method that is discussed in this survey, in order to show the performance of methods.

IV. DEVELOPED BROADCASTING MECHANISMS IN VANETS

Broadcasting will play an important role in vehicular communication when disseminating messages such as emergency warning and information about unsafe driving conditions. However, the lack of packet acknowledgement and packet re-transmission renders it difficult to achieve high broadcast reliability due to wireless contention and interferences in the medium. Unlike unicast, the optional RTS/CTS handshake to prevent the hidden terminal problem in 802.11 cannot be used for broadcast since the RTS/CTS exchange would cause even more packet flooding and increase the broadcast storm problem. Additionally, maintaining high connectivity and high broadcast reliability is difficult, especially in dense networks and with non-homogeneous vehicle mobility. Additionally, in sparse situations connectivity among vehicles is not preserved.

In recent years, different developed algorithms have been suggested to solve the mentioned problems of broadcasting in vehicular networks. We categorized all the improved broadcasting algorithms in VANETs in the following groups.

1. Controlled Repetition Based Mechanisms

In order to increase the reliability and reachability of high priority safety messages, the *Repetition* technique is used. In this technique, a message is disseminated more than once. However, as repeating packets increase the collisions in the network which may lead to the broadcast storm problem, different solutions have been proposed to control the number of messages in order to overcome the broadcast storm problems.

In [21] the authors use the repetition technique in VANETs with a fixed number of vehicles. They show via simulation that the reliability and throughput of the system are improved using repetition of each packet in each message. Additionally, they determine the optimum number of repetitions in the vehicle-to-vehicle mode.

The authors in [22] propose controlled repetition technique to improve the performance of the system. They enhance the repetition-based broadcasting mechanism by applying a piggyback technique for the dissemination of safety messages. Further, they control the number of repetitions by adding one byte overhead to the data frame in the vehicle-to-vehicle mode. Also, they determine an optimum value for the piggyback header and analyse the average end-to-end delay for the three safety message priority classes. In continuation of this work, the authors in [22] propose a stochastic technique using repetition technique to control the broadcast storm problem with probabilistic retransmitting of messages. They show the importance of using controlled repetition and stochastic techniques. Moreover they show that the proposed method can overcome the lack of handshaking procedures in transmissions of safety messages in VANETs.

2. Distance Based Mechanisms

In the group of *Distance based* mechanisms the next node to repeat the message is selected based on its distance from the previous transmitter. It is obvious that if the distance between the source node which disseminates the alert message (alert source) and the next repeater is longer, the coverage area in each step will be larger in a broadcast procedure and consequently the number of hops and message delay decrease. Fig.1 shows how this method works in the network. As it is shown in the figure, node C_2 which is further from the source is selected to retransmit the alert message.

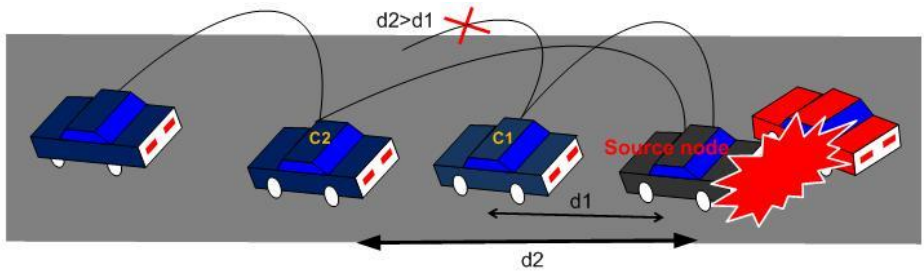

Fig.1. A distance based scenario ($d_2>d_1$, C_2 is selected to rebroadcast the message)

In [7], authors propose a new efficient IEEE 802.11 based Urban Multi-hop Broadcast protocol (UMB) for ad-hoc vehicular networks. They change IEEE 802.11 frames to piggyback the location of the previous relays on them. Also, they use RTB (Request to Broadcast) and CTB (Clear to Broadcast), respectively to send data packets. In this method, in order to select the optimal node to rebroadcast the packets, the transmission range (R) is divided into segments. To select the next repeater, the alert source broadcasts an RTB packet. When the nodes in the transmission range of the source receive this RTB packet, they send out a black-burst signal [23]. The length of the black burst is proportional to its segment distance from the RTB sender. At the end of the black-burst, nodes listen to the channel. If a node finds the channel empty, it means that its black-burst was the longest and that it is now responsible for replying with a CTB packet. In this method, most of the time one node is selected to rebroadcast the messages. However, several nodes may exist in the last non-empty segment, which means that their CTB packets will collide. To solve this problem, the authors propose that the last segment should be further divided into sub segments. However, it is obvious that their solution may lead to a slow rebroadcast procedure in dense networks, because of the contention problem between several nodes. In addition, the authors consider an intersection broadcast scenario [7]. In this case, some fixed (non-vehicle) repeaters placed at the intersections broadcast the messages in all directions. These repeaters have large transmission range and they may cover other intersections, therefore, it is probable that there are packet loops. In order to solve this problem, the authors propose that the repeaters at the intersections record the packet IDs, and that they refuse forwarding a packet if they have already received and forwarded the packet. Finally, using a simulation approach, the authors show that their solution improves success percentage, packet dissemination speed and load generated per broadcast packet in comparison with similar algorithms [24].

A distributed position–based broadcast protocol, named Smart Broadcast (SB) protocol is presented in [25]. Similar to UMB [7], the coverage area can be partitioned in adjacent sectors and nodes are capable of estimating their own position and, therefore, the sector they belong to. Hence, a contention–resolution procedure is performed to elect the relay node. Conversely to the other schemes, the SB does not necessarily select the relay in the region that provides the largest progress, since it does not spend time to resolve collisions. When performing the one hop broadcast, the minimization of the time is, indeed, the main target of the SB protocol. Finally, the authors maximize the progress of the message along the propagation line, and minimize the rebroadcast delay through a mathematical model. They show that the message dissemination speed and the one-hop message delay are improved in comparison with UMB and Geographic Random Forwarding (GeRaf) mechanisms [26]. In [27], the authors propose a cluster based dissemination protocol which follows the distance based mechanisms. However, in this protocol, the furthest cluster is selected as the next forwarder. It should be noted that in each cluster, the message is disseminated in a proactive approach (i.e.by using route tables). The authors compare their approach with the Routing protocol for Emergency Applications in Car- to- Car networks using Trajectories (REACT approach) [28], and show that fewer messages are required to disseminate an emergency message. However, the speed and velocity of the simulated vehicles are not mentioned in this paper. It can be argued that, by considering the velocity of the vehicles, frequent changes in the clusters members and routing are experienced should be considered.

The authors in [29] propose an Adaptive Probability Alert protocol (APAL) to solve the broadcast storm problem in the network. This method is the adaptive version of the The Last One (TLO) [30] protocol in which the node furthest from the place of the source node is selected to rebroadcast the message. APAL utilizes adaptive wait-windows and adaptive probability to rebroadcast. This scheme shows even better performance than the TLO scheme; however it is only validated in highway scenarios.

The authors in [31] present the backfire mechanism where a node efficiently forward a message based on its distance from the source. It means that each node after receiving the message set a time to rebroadcast the message. The waiting time is inversely proportional to the distance from the source. Finally, when a node with smaller waiting time rebroadcasts the message, other nodes, after receiving the same message, refrain themselves from rebroadcasting the message.

The adaptive version of the previous mechanism intended to solve the problem of redundant forwarding of the messages is presented in [32]. It uses a dynamic backfire algorithm to dynamically adjust the area within which the forwarders have to be refrained from rebroadcasting the messages based on the density of their neighbours. Vehicles compute the density of neighbour nodes to calculate a forwarding sector in which vehicles are not allowed to rebroadcast the message. Simulation results show that the proposed mechanism improve the dissemination process in terms of removal of the forwarding of redundant messages and packet delivery ratio.

3. Location Based Mechanisms

In the group of *Location based* mechanisms, the goal is to select the node that covers the largest area in the message propagation direction. These mechanisms are different from distance based mechanisms, since broadcasting direction is considered in this case. Fig.2. shows that despite the existence of node C_2 which is further from the source; node C_1 in the message propagation direction is selected as a next repeater.

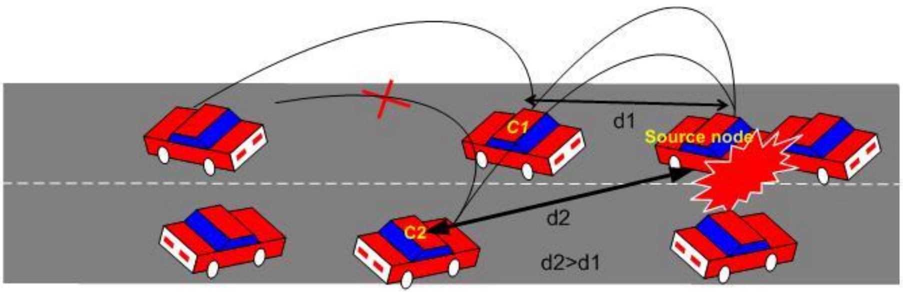

Fig.2. A location based scenario (d2> d1but the message should be broadcasted in the message propagation direction)

Authors in [6] propose a position based multi-hop broadcast protocol (PMBP) for emergency message dissemination. In this scheme the candidate node to forward an emergency message is selected according to its distance from the source vehicle in the message propagation direction. In the proposed scheme, an emergency message is protected by BRTS/BCTS (Broadcast Request to Sends/Broadcast Clear to Send) handshake. After receiving BRTS, each node starts a defer timer and prepare to reply a BCTS message. A timer is set according to both the distance to the source node and the distance to the current relaying node. Therefore, the furthest neighbouring node from the previous relay in the message propagation direction defers the least time, and has the highest priority to reply a BCTS packet. Simulation results show that message delay, number of broadcasting hops and channel occupancy time are improved in comparison with the simple flooding algorithm.

In [8] a method is presented based on the furthest distance. In this method, each node knows the location of its neighbours by using beacon messages. In addition, each node knows the direction of broadcasting and maximum transmission range of other nodes. Based on this information, the last node in the transmission range of the previous relay is selected to rebroadcast the message. The authors show that the proposed method improves the number of collisions and the time to send in comparison with weighted p-persistent method (to be described in group 4). One of the drawbacks of the proposed method is that location changes of the nodes are not considered in the time interval between two transmitted beacons. A solution to this problem is to add the velocity of the vehicles to the beacons and to increase the sending rate of beacons for the vehicles moving fast. Some schemes in this group use a different approach. In these methods, the transmitter node, by using some information from its neighbours selects the next relay to rebroadcast the messages. The amount of overhead introduced by this scheme may be high as the scheme requires that each node have perfect knowledge about its one-hop and two-hop neighbours in real time, in order to properly choose the set of relay nodes. Additionally in some conditions, this information is not exact and has a short life time [9].

Broadcasting at an intersection is very challenging, since vehicles in each of the roads constituting the intersection can affect the broadcast process of other roads and messages, which means that the message may not be propagated in some directions. The authors in [33] present a cross layered MAC and routing solution to support the fast propagation of broadcast messages at intersections. The authors use a distance based mechanism in a one-way road scenario. This means that the furthest node is selected as a repeater. Additionally, if the nodes receive the specific message twice, they refuse repeating the message. The second reception may show that there is a neighbour node that has disseminated the message. Therefore, sometimes, this method leads to a stop in the broadcasting procedure. To avoid this phenomenon, the authors propose a method to determine the moving directions of vehicles using the angle between their moving directions. In this solution, if the node, which has received the message twice, has the same direction as the previous relay, it should rebroadcast the message. Finally, simulation results reveal the improvement of the proposed method in comparison with an ordinary distance based method.

In [34], the authors propose a location based scheme. In the first phase of the protocol, the neighbours moving toward the destination (approaching vehicles) are estimated. In the second phase, between the selected nodes in the previous phase, the node with the least perpendicular distance to the shortest path between the source and destination is selected as the next forwarded. This selection mechanism minimizes the total transmission distance of the packets and it is performed using the locations of the source, destination and potential forwarders. Therefore, in this scheme, the propagation delay is minimized by monitoring the motion vector of the forwarding vehicles and minimizing the transmission distance of the packets. Simulation results show improvement in end to end delay and transmission distance in comparison with the Motion Vector (MoVe) protocol [35].

Direction aware broadcast forwarding, a simple yet efficient method, is introduced in [36]. In the paper, the authors describe two versions of direction-aware broadcast called naive and intelligent broadcast methods. In naive broadcast, if the vehicle detects an emergency event, it will transmit warnings periodically. Upon receiving a warning, the other vehicles start transmitting their own periodical warnings if the message they received came from their front. In intelligent broadcast with implicit acknowledgement, both the initiators as well as the repeaters cancel their periodical transmission when they hear the same warning coming from a node at their back. All receivers wait for a random time before starting to send their own warnings, in order to determine whether another node starts before them. If a node hears that another node transmits the warning, it concludes that the warning has already propagated successfully, and therefore refuses to send the messages. Simulation results show a significant improvement in terms of the success ratio under high background traffic and packet error rates when using the intelligent version.

4. Stochastic/Probabilistic Mechanisms

In the group of *Stochastic or Probabilistic* mechanisms, authors try to optimize the probability of rebroadcasting in order to minimize the network collision. Generally, a stochastic mechanism can be categorized as shown in Fig.3. We can explain this diagram as follows: Stochastic mechanisms are generally classified into two groups: fixed stochastic mechanisms and dynamic stochastic mechanisms. Fixed stochastic mechanisms are sometimes known as Gossip based mechanisms. These schemes enforce each node to rebroadcast received messages with a fixed probability [9]. This probability can be selected based on the network density. Setting the forwarding probability to a proper value yields a proper threshold between reachability and overhead in the network.

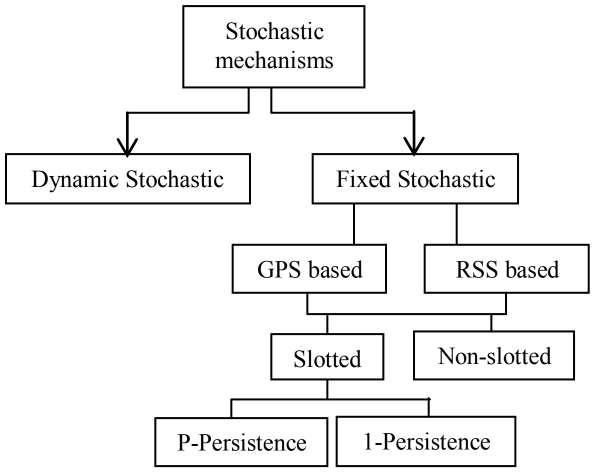

Fig.3. Classification of stochastic mechanisms

In dynamic stochastic schemes, each node rebroadcasts the received messages with some probability which is not the same for all nodes. This probability is determined during runtime, and it is based on factors such as distance from the last hop neighbour, distance from the broadcast origination, etc. These schemes can be further categorized into two groups; GPS based and Received-Signal-Strength (RSS) based algorithm.

In the following, some papers based on stochastic mechanisms are explained. In [9], the authors propose a stochastic solution based on GPS and RSS. It is shown that the proposed schemes can reduce broadcast redundancy and packet loss ratio by up to 70 percent while still offering acceptable end-to-end delay for most multi-hop VANET applications. It is worth to know, that all the previously mentioned algorithms assume that, if a node receives the packet for the first time, it rebroadcasts the packet, otherwise, it discards the packet. GPS and RSS based solutions are both divided into two groups; i) Non-slotted solutions (Weighted p-Persistence broadcasting) and, ii) Slotted solutions.

Weighted p-persistence assigns higher probability to nodes that are located further away from the broadcaster. Denoting the relative distance between nodes *i* and *j* by D_{ij} and the average transmission range by R, the forwarding probability, p_{ij}, are proportional to D_{ij} and inversely proportional to R. In order to prevent message *die out* and to guarantee 100 percent reachability, node j should rebroadcast the message with probability 1 after a while (specific waiting time) if it does not hear any retransmission from its neighbours.

Slotted solutions can additionally be divided into slotted 1-Persistence and slotted P-persistence categories. In slotted 1-Persistence methods, each node checks the packet ID and rebroadcasts with probability 1 at the assigned time slot TS_{ij} if it receives the packet for the first time and it has not received any duplicates before its assigned time slot; otherwise, it discards the packet. TS_{ij} is calculated in a way in which nodes that are further away from the broadcaster have a lower waiting time than the others [9]. The slotted P-persistence mechanism is similar to 1-persistence, however in this scheme, a node after checking the packet ID; rebroadcast the packet with probability P. This technique can be modified to use the packet received signal strength information instead of GPS. In the absence of GPS, each node can, at best, obtain the RSS of the broadcast packet received from the DSRC device driver and determine whether or not to rebroadcast the packet based on the instantaneous RSS measured and prior knowledge of transmission power and receiver sensitivity [9] [11] [13]. One of the drawbacks of RSS method is that all the vehicles should be equipped with the similar DSRC device.

The authors in [14] propose that stochastic methods based on RSS can mitigate the broadcast storm problem in VANETs. They enhance the controlled repetition broadcasting mechanism by applying a stochastic technique for the dissemination of safety messages based on an IEEE 802.11e medium access protocol. At first, they simulate their proposed scenario while all nodes are given a uniform and constant retransmission probability. Additionally, they simulate a scenario where the retransmission probability is dynamically determined based on the distance between the receiver node and the last hop (nodes that are further from their last hop have a higher probability of retransmission). They show that by using the dynamic stochastic method, a better throughput is achieved in comparison with the fixed stochastic technique. This phenomenon is the result of suitable selection of relays. Further, they show that when using a stochastic method in the network, the number of collisions is reduced.

The authors of [37] claim that the main driver for network performance is connectivity, and they state that collisions at the MAC layer have a negligible effect on service reliability. They consider a highway scenario, where the warning service triggered in an emergency employs multiple broadcast cycles to guarantee the desired lifetime for the safety area. The next node to take over the message delivery task is chosen probabilistically. The authors develop an analytical model to predict the reliability of a single broadcast cycle. In this method, the average number of nodes in a node's neighbourhood and the distribution of the space to be covered by the next message are calculated. Additionally, the simulation results show the validation of the authors' analysis.

5. Channel Reservation Mechanisms

Previous broadcast schemes are dynamic, i.e., each node should compete with others in order to send data in a slot. Dynamic methods may lead to contention and consequently to collision problems, and therefore, some authors propose to use static methods in VANETs. In [39], the authors propose a static scheme to broadcast the messages with low end-to-end delay. In this scheme, transmission time is segmented some slots. All the neighbours of each node reserve one set of these slots for data transmission. These reservations are saved in a Bitmap like data structure and then announced to all the neighbours. Each node must reserve the proper numbers of slots: If the number of allocated slots is more than the number of neighbours, some slots will be empty and consequently network delays will be increased. This means that each sending neighbour, after using its slot in the current round, must wait for its slot in the next round while there are some empty slots in the current round. On the other hand, if the number of slots is less than the number of neighbours, some neighbours may not access the channel. So, in order to achieve better performance, neighbour discovery protocol should be added to this scheme. A distinctive feature of this scheme is its distributed design with fast schedule reconfiguration to cope with vehicular topology changes.

The authors in [38] present an adaptive multi-channel mechanism to enhance the adaptability of the MAC protocol to different traffic density conditions. Similar to what has been performed in [39] each node can reserve a set of time slots during the message broadcasting to communicate with its neighbours, however this work is based on a hybrid channel access mechanism exploiting both the advantages of TDMA and CSMA/CA. In this protocol, each time slot consists of a control channel (CCH) and a service channel (SCH) according to Fig.4. Each time slot in SCH is dynamically reserved in CCH by an active vehicle. The SCH uses TDMA as its channel access scheme. The length of this interval depends on the network density. In this method, each node constantly sends its reservation information to its neighbours. If one node of the network wants to reserve a slot, it should send a request. If the requesting node receives its reservation information in the next transmission, it can transmit its data in the reserved interval; otherwise, it should send a new request. Finally, the authors show that their proposed method can improve delivery ratio in comparison with the previous works based on WAVE MAC [38].

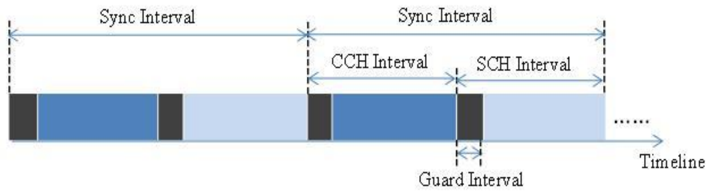

Fig.4. MAC scheme, Sync interval is divided into CCH and SCH

6. Backbone/Shared Tree Based Mechanisms

In the group of *Backbone or Shared Tree based* mechanisms, some algorithms are presented with the objective to find the optimal nodes that can broadcast the messages to all the nodes in the network. These nodes are known as the backbone in the network. As it is shown in Fig.5 only the nodes that belong to a backbone should rebroadcast the message to other nodes. The main problem in this group is maintaining and updating the backbone in highly mobile networks. One of the most important properties of backbone based algorithms is to overcome the broadcast storm problem by decreasing the number of relay nodes in the network. If the backbone nodes are determined, The RTS/CTS mechanism can be used between them which can improve the reliability of the network.

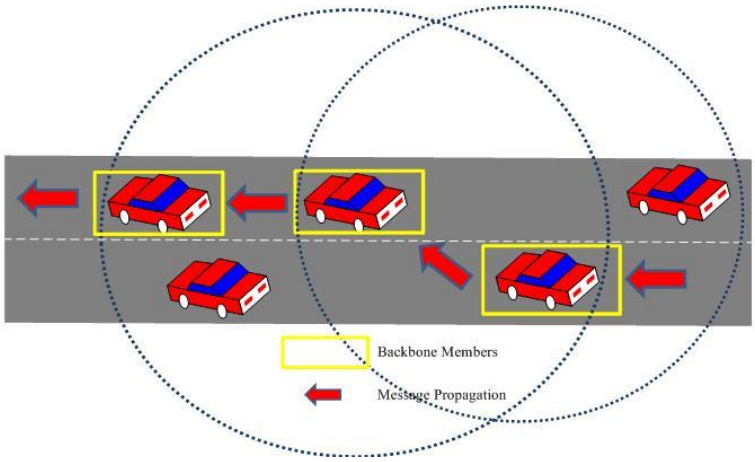

Fig.5. A backbone based scenario, the message have been rebroadcasted only by the backbone members

It is worth mentioning that communication between backbone nodes and non-backbone nodes is accomplished in a broadcast manner. In [40], a distributed and efficient method is presented for efficient construction and maintenance of k-hop dominating sets (backbone) in Mobile Ad Hoc Networks. A k-hop dominating set (K- DS) is a subset of nodes such that each node that is not in the set can be reached within k hops from at least one node in the set. The authors assume that the network is fully connected, which means that there is at least one path between two nodes in the network. Also, they identify a sufficient condition that guarantees the connectivity of the backbone. Message broadcasting in such backbone for the above assumption ensures that all the nodes in the network receive the messages with k hop delay. Regarding the mobility of the nodes in the network, neighbours of each node can be changed at any time, which means that the backbone needs to be upgraded. In the paper, an optimum solution is presented to maintain the k-DS. It is worth mentioning that the construction and maintenance of the k-DS is distributed and obtained by 1-hop neighbour information.

In [41] a method is presented to create and maintain the backbone, when considering also mobility in the network. The authors propose a solution to create a backbone based on three conditions: connectivity, link availability, and consistency. If these three conditions are satisfied in the network, the backbone is constructed according to algorithms [41].

It is obvious that these algorithms for finding the backbone need rapidly changing information on neighbourhoods in order to update the dominating set. This high rate information is inefficient for applications with safety message dissemination. For this reason, the authors in [42] propose a special algorithm to construct a backbone for message broadcasting in VANET. They propose a cross-layered and distributed dynamic algorithm to create a dynamic virtual backbone in the vehicular networks. They define a fast multi-hop MAC forwarding mechanism to exploit the role of backbone nodes. In this paper, the authors develop MAC and network layers. It is worth mentioning that in this algorithm the network is segmented into some clusters. One node is selected in each cluster in order to rebroadcast the messages (Note that these head nodes constitute the virtual back-bone). The selection is based on the maximum distance from previous repeater. In addition to the coverage area, direction of broadcasting and message TTL are determined after generation of each safety message. In order to construct the backbone, authors try to satisfy the following goals: i) backbone stability, where a minimum connectivity-duration threshold is required for a node to become part of the backbone, ii) high nodes distance, where for hop reduction, relaying nodes should be as much distant as possible and iii) management overhead, where the backbone creation should be distributed and based on light communications.

Also, Dynamic Backbone Assisted MAC (DBA-MAC) is proposed in the same paper in order to develop a MAC layer. The DBA-MAC protocol provides differentiated channel accesses reflecting two priority classes (backbone member, normal vehicle) determined in the backbone creation algorithm. Some important goals which are taken into account are as follows: i) exploiting the presence of a backbone structure in the VANET, ii) having fast propagation of multi-hop broadcast messages, and iii) dynamically adapting to network load and cluster variations. Finally, the authors consider a multi-lane highway scenario to analyse the performance of their solutions. They show that the proposed mechanism can improve message delay and packet loss rate in the network in comparison with simple broadcast solutions based on IEEE 802.11[43].

7. Store, Carry and Forward Mechanisms

In the group of *Store, Carry and Forward* methods, denoted SCF, the following scenario is addressed. A vehicle carrying a safety message cannot find any neighbours to rebroadcast the messages to. Therefore, this node saves the messages of that network and carries them until it finds a node in its communication range. After detecting the neighbour, this node rebroadcasts the saved messages. This concept is depicted is illustrated in Fig.6.

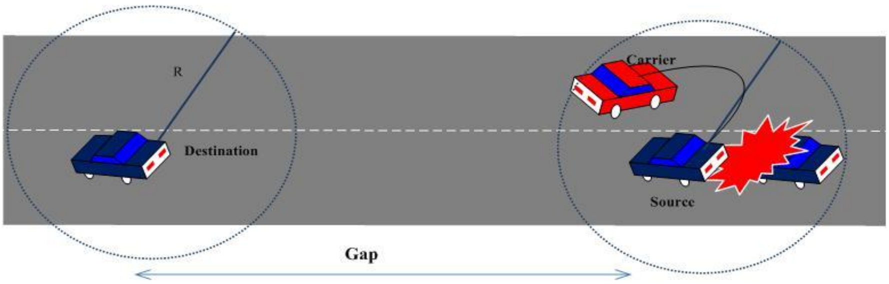

Fig.6. Store, Carry and Forward mechanism: packet cannot immediately be relayed to vehicles in both directions

The authors in [5] use the SCF mechanism in a part of their work. They propose the Distributed Vehicular Broadcast (DV-CAST) protocol that integrates the use of various broadcasting solutions they have previously proposed [9]. They consider three different regimes of vehicle traffic flow in the network: i) dense traffic, ii) sparse traffic, and iii) regular traffic. Different algorithms are presented in order to broadcast messages in each traffic condition. The main goal in this paper is to increase the reachability of the network even when there are no neighbours to broadcast the messages to. In order to accomplish this, each node in the network should obtain its one-hop neighbour information by sending beacon packets. Each node separately decides to rebroadcast the messages. The traffic regime is recognized in the MAC layer and then this information is delivered to the network layer. Based on this information, each node selects a broadcasting method. In dense traffic conditions, the authors propose a stochastic based mechanism for message broadcasting. Also, they propose to use SCF when broadcasting the messages in sparse situations. In these situations, node A may receive the message, however, may not find any neighbours moving in the same direction to rebroadcast the message to. In this case, if node A finds any vehicles in its neighbourhood moving in the opposite direction, it should deliver the message to this node (denoted Node B). Node B saves the message until it detects a neighbour moving in the opposite direction. Notice that if node A cannot find a neighbour in the opposite direction such as node B, it should save the message until it can find a neighbour moving in the same direction or opposite direction. Besides the dense and sparse traffic regimes, the other type of traffic is the general one which is the worst regime. It is worth to know that in the two previous regimes, every vehicle will observe the same local traffic density which reflects the real global traffic density. However, in a regular traffic regime, not all vehicles observe the same local traffic type, i.e., some may have very few neighbours while some have many neighbours. In this case, some vehicles will have to apply the broadcast stochastic algorithm while some will have to store-carry-forward the message in order to preserve the network connectivity. One of the problems in [5], is using beacon packets in dense regime that can lead to increasing amount of collisions and contention in the network. In our opinion, controlling the beacon sending rate based on the traffic conditions may solve this problem.

In [44], a method is presented based on an SCF mechanism in the application layer. Each node saves and disseminates new data if this data provides more knowledge in comparison with previous received data; therefore, the numbers of retransmissions will be reduced in the network. Such methods are implemented in the application layer, since a specific weight is dedicated to each message to indicate the discrepancy of the received per-segment data compared to the node's previous knowledge. This method, like other SCF methods can increase reachability in the network.

Also in [45], a method is proposed based on an SCF mechanism to forward the messages. The main goal of this paper is to efficiently route the packet to fixed sites and receive the reply within a reasonable delay by selecting the best route for the SCF mechanism. The authors present an analytical model by writing pre-estimated delay equations in each road. Analytical and simulation results show that the delivery ratio, packet delay and traffic overhead are improved in comparison with GPSR and Epidemic algorithms [15], [16].

The authors in [20] propose Directional SCF (DSCF) which employs the directional antennas. They investigate several characteristics of the broadcast communication with DSCF in two-dimensional road models through simulation. Simulation results show that, except for the too low density situation, DSCF performs well in terms of dissemination speed, uniformity, reliability, and efficiency in all situations.

8. Power Based Mechanisms

In the group of *Power based* mechanisms, solutions are proposed to dynamically control the communication range for vehicles by adjusting the transmission power to mitigate the effects of broadcast storm.

The authors in [17] investigate safety applications in highways with shockwave mobility and different lane configurations for VANETs. Shockwave on highways is a common phenomenon that occurs every day along with the formation and propagation of traffic queues. A shockwave separates two traffic streams and the two traffic streams have different traffic densities, hence different speed according to the fundamental traffic flow relationships. This paper proposes a mechanism to dynamically control the communication range for vehicles by adjusting the transmission power to mitigate the effects of broadcast storm and decrease the numbers of collision packets in the network. The authors argue that it is generally accepted that, for uninterrupted traffic flow, there is a density-speed relationship; therefore, they use this relationship to estimate the network density. The transmission power is controlled by estimating the network density using the vehicles' speed. Finally, the paper shows the benefits of employing dynamic transmission ranges on a highway with shockwave mobility that inter-mixes free flow and congested flow traffic. Also it shows that lane configurations can have a major impact on the performance measures such as delivery ratio and packet reception ratio.

In [19], the authors propose to adjust the transmission power and communication range to improve the network performance. At a high density network, each node limits its communication range by decreasing the transmission power. Conversely, in the low density situation, each node should increase the transmission power to maximize the coverage area. In order to estimate the density in the network, the authors use a density-speed relationship. Finally, they mitigate the broadcast storm problem using their proposed methods.

In addition to above works, some papers have focused on adaptive version of the power control mechanisms. In [46], the authors propose a transmission range adaptive broadcast algorithm. They select the optimum relay nodes by deriving waiting time based on additional coverage area. Based on this waiting time, a node with larger transmission range and further from the previous relay is selected as a current relay. Therefore, fewer hops are required to forward packets. It is worth mentioning that, the connectivity gap is eliminated with packet forwarding in the opposite lane. Additionally, the authors present the implicit ACK and the explicit ACK methods to control the message dissemination based on regional and time restrictions. Therefore, simulation results show improvement in reachability and end-to-end delay in comparison with some simple location based algorithms.

Additionally in [47], the authors present Efficient Transmit Power Control (ETPC) to focus on increasing the packet reception probabilities for near vehicles, while trying to keep the transmission range as large as possible. ETPC conducts power control by piggybacking power setting messages onto the broadcast beacons. It is worth mentioning that the authors use beacon load greater than a certain threshold to identify whether power control is needed. Using this, they call a vehicle a victim if it has a beacon load greater than the threshold, and therefore, they make ETPC applicable for dense scenarios by reducing the transmission power by victims and other vehicles that can directly reach these victims. As a result, this approach can reduce the beacon load of victims. However, recipients close to the senders with reduced transmission powers may not be able to benefit from the power reduction because of the increased number of hidden terminals. This phenomenon is called an "unbalanced interference". In order to avoid unbalance interferences, the authors propose a solution in which other vehicles should additionally set their transmission powers to a new value. Therefore, the new transmission power is propagated to other vehicles via broadcasts. Finally, simulation results show that ETPC has the better performance than Distributed Fair Transmit Power Adjustment (D-FPAV) [48] in urban scenarios, while showing comparable performance in highway scenarios.

9. Priority Based Mechanisms

Priority based mechanisms differentiate the service quality based on the message priorities. These solutions use different service quality parameters for each priority class to provide different access qualities to the network. A safety message should propagate from a source as far as required informing as many nodes as possible with minimum delay and maximum reliability. This can be achieved by employing the priority based mechanisms and assigning a high priority class to these safety messages.

In [21] and [22], the authors propose a mechanism based on IEEE 802.11e. They focus on a Differential Services mechanism to differentiate messages based on their priorities as suggested in IEEE 802.11e. They define three priorities for safety messages as follows: Pri(1) is defined as an accident type, Pri(2) is defined as a warning message and Pri(3) is defined as a general message. The messages are transmitted repeatedly, where the number of repetitions is assigned based on the priority of a message. Therefore, to increase the probability of a successful transmission for high priority messages, a high priority message is transmitted more times than a lower priority message. Finally, the authors show that by defining the different classes of safety-related services, the main performance measures of safety messages dissemination are improved.

In [49], the authors propose a protocol that enhances the multi-access policies of the original 802.11e protocol. In this protocol, each node first estimates the contention level of the channel using the number of lost messages. Then, based on the estimation, each node adjusts its non-safety traffic volume. Simulation results show that the 802.11e enhanced protocol exhibits an improvement of 10% in message reception rate and 45% in medium access delay compared to the original 802.11e protocol.

In [1], the authors propose an adaptive beaconing based scheme. It is worth mentioning that beaconing in this work is not employed for topology maintenance, rather it is used for data transport. In this paper, the beacon interval is calculated based on the two parameters "channel quality" (C) and "message utility" (P). The C parameter is a linear combination of the number of collisions, SNR and number of neighbours for each node. The P parameter is derived from the distance of the vehicle from the event and the message age, thus allowing newer and important messages to be disseminated faster.

10. Other Solutions

Alongside the categorized solutions, there is some work that cannot be categorized in any of the above mentioned groups. These methods are described in this section.

In [50], the following three mechanisms are proposed for safety message broadcasting: i) congestion control mechanism, ii) broadcast performance mechanism, and iii) concurrent multichannel operation for safety and non-safety applications. First, the congestion control method is described. The authors argue that the broadcasting quality of safety messages depends on the message size and network congestion. They propose that each sender estimates the overall competition for channel usage and adjust its bandwidth usage accordingly. This means that each vehicle needs to ensure that its contribution to communication density is a fair share of a targeted channel-congestion level. One key concern with the above concept is timing. For example, it takes a bit of time for a vehicle approaching a crossroad to realize the increasing number of vehicles around it. As it adjusts for the extra competition on the channel, it has already moved beyond the spot. Accordingly, congestion control requires a protocol through which vehicles can disseminate the density conditions quickly.

The second solution in [50] attempts to improve the average reception rate of routine safety messages while ensuring the best possible reception rate for each event safety message. They propose a Piggybacked Acknowledgment (PACK) protocol. In this method, an individual vehicle is able to quickly collect feedback on its recent broadcast message, if other vehicles piggyback some acknowledgments about previously received messages in their new messages. This makes the safety applications informed of each message performance, which may be selectively retransmitted if necessary.

The authors' third proposed solution is as follows. As safety message content is small, each node piggybacks new ordinary safety messages in its event safety messages. If there are more than one such message, the sender is required to include the IDs of the additional event safety messages as well. In VANETs, a vehicle operating in a service channel must regularly switch back to the control channel and transmit its safety messages as usual. While a node is on the control channel, if it hears indication of an event safety message with unknown ID in the piggyback IDs, it is required to remain in the control channel to receive the message with the unknown ID. Therefore, the nodes receive all the event safety messages according to the above solution. Simulation results show the efficiency of the above three mechanisms.

Security mechanisms are proposed to broadcast the safety messages to secure VANETs against abuse. In [51], the authors propose a secure MAC protocol for VANETs, with different message priorities for different types of applications to access DSRC channels. The secure communication protocol is designed using time stamp, digital signatures, and certificates to guarantee the freshness of the message, message authentication and integrity, its non-repudiation, and privacy and anonymity of the senders.

Broadcasting methods are presented for special applications in different papers. For example, in [52], the authors propose that safety messages should be disseminated to both front and back sides of each source. They consider a special scenario that an ambulance is passing through a road. The authors determine the distance between the ambulance and other nodes using a simple equation based on position and speed of nodes. Then, some nodes based on their distance from the ambulance retransmit the message twice. Finally, the authors show that network reliability is improved with their proposed method.

In [12], the authors propose the following three different methods for message broadcasting: i) Data Pouring (DP), ii) Reliable Data Pouring (RDP), and iii) Data Pouring with Intersection Buffering (DP-IB). In DP, packets are periodically broadcasted to vehicles on the road. In DP, similar to Opportunistic Dissemination (OD) [53], a fixed node rebroadcasts the message and delivers it to the nearest nodes. Then these nodes rebroadcast the message to their neighbours. In RDP, to ensure that vehicles receive the disseminated data, request to send/clear to send (RTS/CTS) handshakes are used, in order to reduce collisions and hidden-node problems. In DP with intersection buffering (DP-IB), data poured from the source are buffered and rebroadcasted at the intersections. The authors present analytical models to explore the dissemination capacity (DC) of the proposed schemes. The analytical models additionally provide guidelines on choosing the system parameters to maximize the DC. Simulation results show that the proposed DP-IB scheme can significantly improve the data delivery ratio, bandwidth efficiency and reduce network traffic.

In [54], the authors propose a Distribution Adaptive Distance (DAD) method to perform well in one-dimensional or two-dimensional uniformly distributed networks. They propose using the quadrat method of spatial analysis to characterize the distribution pattern at each node and to use the local node density and some resulting metrics (for example, expected number of transmitters in a circle of radius r) as the factors in computing the threshold function. The optimal value of the threshold is depending on the node density and distribution pattern. Simulation results show that the DAD method can improve reachability and efficiency in both the pure linear and the pure two-dimensional distribution patterns.

A multicast routing scheme for dissemination of safety messages is presented in [55]. The authors apply an adaptive transmission range in cooperative collision warning system (CCWS). The first objective is to reduce unnecessary transmission by sending warning messages to vehicles that are endangered. At the same time, the receivers can be prioritized based on their critical time to avoid accident, ensuring in-time delivery of the warning messages. This critical time is computed based on a well-known delay-constrained minimum Steiner tree (D-CMST). The second objective is to minimize the transmission range using an adaptive transmitter power control. This objective is achieved by using the cost function that is proportional to the distance between two points in the graph. By minimizing the transmission range, they reduce radio interference thus increasing the network capacity. However, using a smaller range may result in increasing the end-to-end delay. They solve this problem by defining a D-CMST.

A simple selective broadcast algorithm, called edge-aware epidemic protocol, is introduced in [56]. According to this algorithm, only nodes at the boundary of a cluster of vehicles propagate messages, either instantly or in a store-and-forward fashion, thus keeping it alive when there is a disconnection in the network. Upon receiving a warning, nodes enter a random waiting period, the duration of which is inversely proportional with their distance to the sender of the message. During this period, the nodes count the replicas they receive, in and against the desired flow of information separately, so they can use this information later to decide whether or not to forward the warning. This logic encourages those nodes closer to the edge of the sender's transmission range to relay the message, trying to increase the one-hop progress it makes. Finally, simulation results show that the proposed protocol outperforms flooding in terms of successful information dissemination.

V. DISCUSSION

In this section we review some comparable properties of the presented work, which can be of help when selecting the proper method for a special environment. It is worth mentioning that although there are studies (e.g. [57-58]) which have evaluated previous work, the literature currently lacks a comprehensive comparison of the algorithms in a unified simulation environment. Also, it should be noted that the best choice for some applications is to use a mixture of the mentioned methods. In our opinion, the methods described before can be divided into cluster and non-cluster based groups which are discussed below (Fig.7 shows the general view of this classification).

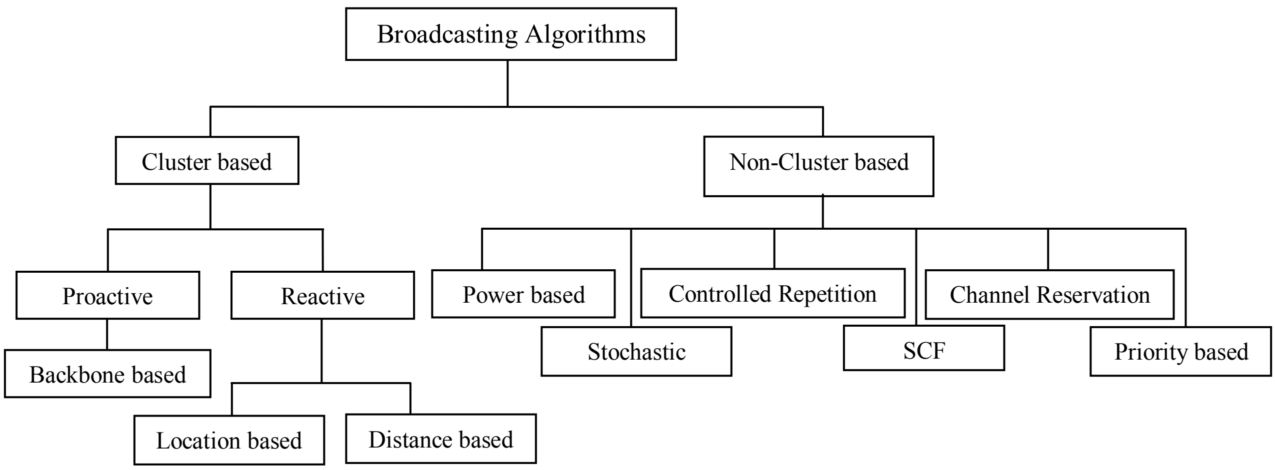

Fig.7. General view of the broadcasting algorithms classification

In the cluster based group, a collection of nodes (and not all of them) are responsible for the rebroadcast of a message. Methods in this group can further be divided into two subgroups: reactive methods and proactive methods. In the proactive subgroup, which only contains the backbone based methods, the relaying nodes are selected *before* the message is generated. In contrast, in the methods that are categorized into the reactive subgroup (e.g., location and distance based methods), the relays are selected *after* generating the safety messages. To have a comparison, it should be noted that, although the proactive methods do not impose the runtime overhead of selecting the relaying nodes, the large number of nodes and their high mobility make such approaches impractical [7]. On the other hand, proactive methods need a prior knowledge of the network topology which is another drawback of these methods. In Table 1, some of the mentioned work and their corresponding features are described.

For evaluation of the reactive cluster based methods, we compare them with the stochastic and controlled repetition based methods. Among reactive cluster based methods, [57] compares the distance-based and location-based methods with the stochastic and controlled repetition based ones. The results show that if location information is available through devices such as

GPS receivers, the location-based scheme is the best choice because the scheme can eliminate even more redundant rebroadcasts for all kinds of host distributions without compromising the reachability. Nevertheless, the need for GPS (as it may not be available in some areas) is a drawback of some of these methods. Using the alternative RSS based method may not solve this problem because due to the channel fading, the RSS is not always accurate. As mentioned earlier, instead of RSS, some papers (e.g. [23]) use the black burst to select the next relay. The black bursts may work fine when the broadcast protocol is the only protocol executed in a special environment. However, in our opinion, when other protocols run concurrently with these protocols it may not be good to use black bursts. This is due to the inaccuracy of the black bursts caused by collision with the neighbour messages.

Another subgroup in the reactive cluster based groups which should be discussed is the distance based group. In our opinion, this group of methods may not be applicable in real scenarios as it does not regard the speed and velocity of the neighbours in selecting the next relay and just selects the furthest neighbour. To make this clear it should be noted that the nodes that are on the border of the neighbourhood circle (further nodes) and that have a high speed are more probable to abandon the circle at the time of sending the message. On the other hand, one of the intermediate closer nodes, based on its speed, may be on the circle border, at the time of sending the message. This argument can be extended to location based mechanisms.

One of the notable groups of methods in the non-clustered based group is the group of power based mechanisms. It is worth mentioning that this group of methods is not appropriate for the scenarios in which there are too much traffic regime changes (e.g. urban areas). This is due to that not estimating the traffic regime is much better than estimating a wrong traffic regime and adjusting the transmission based on that wrong estimation.

To summarize this section, in Table 1 some features of the previous work are compared. To have a quantitative comparison between the papers, in Table 2 we mention some of the results. Most of the results in Table 2 are selected from the papers that compared their proposed algorithms with the simple flooding based approach. The results (which are selected from the best cases in the simulation results of the corresponding paper), are translated in percentages to make the comparison easier (e.g. the first row of the table illustrates that [7] shows a 50% of reception rate improvement to the 802.11 random case). Also, in Table 3 we compare the various broadcasting groups to show which requirements they fulfil.

Also, security and anonymity are two important requirements, which should be regarded in future proposed broadcast protocols. This is due to that in safety-related messages; the human's life is at stake. Further, the anonymity is an important desirable feature. However, in most of the previous methods (e.g. channel reservation protocols) the User ID is used for beaconing and this causes a lack of the anonymity.

VI. CONCLUSION

This article has presented a wide range of different broadcasting algorithms proposed for VANETs. Broadcasting in VANETs is very different from broadcasting in mobile ad hoc networks due to the different properties and requirements. These differences show that conventional dissemination will not be applicable for most vehicular broadcast applications. In this paper, we first introduce the current requirements for designing broadcasting algorithms in vehicular networks. Then, we present some evaluation metrics that were used to evaluate the performance of vehicular networks in broadcasting mode. After that, some of the current broadcasting algorithms are summarized and classified into 10 groups. Finally, we provide a comparison of the various groups, showing how they work efficiently in different scenarios and applications. All the groups are trying to improve the broadcasting performance somehow but, it is important to select the right broadcasting algorithm among them in different conditions.

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Table.1. Comparison of some features of presented algorithms

Reference no.	Group Name	F1	F2	F3	F4	F5	F6
7	Distance based	No	URBAN	No	Yes	No	Road Map
5	Distance based and SCF	Yes	All traffic regimes*	No	Yes	No	-
8	Location based	Yes	Dense and Regular	No	Yes	No	-
25	Distance based	Yes	Dense and Regular	No	Yes	No	-
9	Stochastic	Yes	Major Highways	No	Yes	No	
17	Hardware/Power based	No	Shockwave	No	No	Yes	Traffic type recognition
38	Channel Reservation	No	Dense and Regular	No	Yes	Yes	-
12	Other solutions	No	All traffic regimes	Yes	Yes	No	Repeaters
20	SCF	No	All traffic regimes	No	No	Yes	Directional antennas
33	Location based	Yes	Intersections	No	Yes	Yes	Intersection maps
6	Location based	Yes	All traffic regimes	No	Yes	No	Path to the destination
40	Backbone	No	Dense and Regular	Yes	Yes	No	-

F1: need for GPS/RSS, **F2**: The scenario used in, **F3**: need for prior knowledge of the network topology, **F4**: need to use neighbour IDs, **F5**: need some changed in MAC and physical layer, **F6**: other special requirements.

* SCF mechanism is used in sparse traffic regime

** Since authors focus on a well connected network, they only consider the major highways.

Table.2. Quantitative comparison of the presented algorithms

Reference no.	Group Name	Reference no./ algorithm name	Comparison parameter	Improvement percent
7*	Distance based	Simple flooding**	Reception rate	50
7	Distance based	Simple flooding	Load generated per packet	50
7	Distance based	Simple flooding	Dissemination speed	50
8	Location based	Simple flooding	Number of collisions	77
8	Location based	Simple flooding	Time to send	41
25	Distance based	7	Dissemination speed	55
7	Distance based	25	One hop progress	4
9	Stochastic	Simple flooding	Packet loss ratio	91
9	Stochastic	Simple flooding	Number of hops	85
Simple broadcast	Simple broadcast	9	End-to-end delay	88
12	Other solutions	7	Generated Load	76
7	Distance based	12	Delay	25
6	Location based	Simple flooding	Channel occupancy time	60
6	Location based	Simple flooding	End to end delay	78

* This row shows that reference number 6 shows a 50% of reception rate improvement to the simple broadcasting case. Other rows have the same comparison concept.

** Reference 7 uses “IEEE 802.11 random” instead of “Simple flooding”.

Table.3. Comparison of the mentioned broadcasting methods based on fulfillment of different requirements

	R1 Reliability	R2 Robustness	R3 Bandwidth efficiency	R4 Disseminating in the desired directions	R5 Imposing the minimum delay	R6 Independency on centralized station	R7 Fairness	R8 Robustness against the collision	R9 Selecting of the proper transmission power	R10 Security
G1 **Control Repetition Mechanism**	√	*	x	x	x	√	**	x	x	***
G2 **Distance Based Mechanisms**	√	*	√	x	√	√	**	√	x	***
G3 **Location Based Mechanisms**	√	*	√	√	√	√	**	√	x	***
G4 **Stochastic/Probabilistic Mechanisms**	√	*	√	x	√	√	**	√	x	***
G5 **Channel Reservation Mechanisms**	√	*	√	x	√	√	**	√	x	***
G6 **Backbone/Shared tree Based Mechanisms**	√	*	√	x	√	√	**	√	x	***
G7 **Store, Carry and Forward Mechanisms**	√	*	x	x	x	√	**	x	x	***
G8 **Power control Based Mechanisms**	√	*	√	x	x	√	**	√	√	***
G9 **Priority Based Mechanism**	√	*	x	x	√	√	**	x	x	***

*Different groups can be combined to be robust against all possible traffic conditions, e.g., light or moderate traffic, traffic jam.

**Advanced methods such as distributed mobility management systems should be added to broadcasting algorithms which are capable of fairly sharing traffic information among vehicles.

*** Security considerations can be added to different groups.

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