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Research Article

Survey on Broadcasting in VANETs

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Abstract: This study aims to evaluate, categorize and compare the Vehicular Ad-hoc Network (VANET) broadcasting protocols. Massive amount of VANET broadcasting protocols have been proposed in the literature. Aiming efficiency, reliability, scalability and reach-ability each of them adopts certain techniques to provide a certain level of functionality. This study distinguishes the VANET routing protocols in several categorizes according to the applications it may serve. By focusing into broadcasting protocols, the study further divides the reviewed algorithms according to the techniques they used to initiate the communication, which would be either through beaconing, handshaking, or instant broadcasting. These protocols are further classified according to the criteria that have been used to select the next forwarder. The criteria usually influenced by the targeted performance of the technique. Such criteria may include furthest node from the sender, the node with the best link quality, endanger nodes, nodes with high probability of forwarding and backbone nodes. Performance metrics that are used for quantitative evaluation are suggested.

Keywords: Broadcasting, message dissemination, routing, VANETs

INTRODUCTION

Vehicular Adhoc Network (VANET), the emerging technology which allows vehicles on the roads to communicate and exchange information with each other, is recently become one of the hottest topics for research in both academia and industry, not only because it adds a significant contribution to technological research and a new source of revenue for companies, but mainly because its potential applications will directly impact peoples' lives. Rather than comfort applications (traffic management application and infoterment applications), safety applications are considered as the most desirable group of applications that are expected to decrease the number of road accidents and safe lives. In order to warn the drivers about a dangerous situation, an event driven safety massages would be generated when an abnormal condition or imminent danger is detected, so that drivers will be able to avoid danger, or react appropriately in case it cannot be avoided, this group of applications may ~~contains~~ road condition warning, post-crash warning, breakdown warning, emergency vehicle at scene warning.

Figure 1 shows the communication pattern of message broadcasting applications in VANET, this type of communication would require backward (e.g., Vehicles behind the sender would like to know about the upcoming hazard situation) or forward (e.g., Emergency vehicle at scene application) rebroadcasting of data message from source to all nodes in n-hop neighborhood. In these types of applications, messages uses small payload, high priority, time sensitive and disseminated within a certain area. Recently a significant volume of routing and disseminating

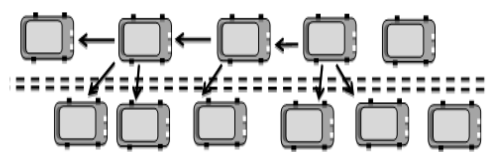

Fig. 1: Communication pattern for message broadcasting in VANET

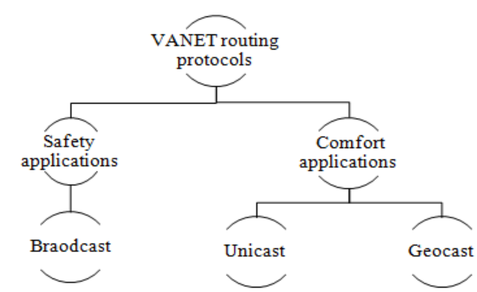

Fig. 2: VANET routing taxonomy

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Table 1: Performance metrics for VANET broadcasting protocols

Network characteristic	Definition	Performance metric	Description
Reliability	The ability of the message to be delivered in despite of some link failure	Delivery ratio	Measure the ratio of the vehicles in network that have successfully received the message
Reach-ability	The number of vehicles could reached by the message if flooding is used	Reception rate	The ratio between number of vehicles that actually receive the message and that could receive it if flooding used
Scalability	The ability of the network to handle more participants	Overhead	Total number of bits (without payload) used to broadcast a packet
		Forwarder ratio	Ratio of the vehicle that forward message
		Broadcast overhead	Number of duplicated messages that received by vehicle
Delay	The time the packet takes to be successfully received	End to end delay	Time it takes the packet to traverse from source to destination
		Latency	Times it takes packet to be successfully received by next vehicle

protocols have been proposed in the literature. Some of these protocols are applicable for safety application (Ros *et al*., 2009; Qiong and Lianfeng, 2010; Schwartz *et al*., 2010) and many others target comfort applications (Wegener *et al*., 2007; Ghafoor and Aziz, 2011; Allal and Boudjit, 2012).

This study will classify VANET routing protocols according to the type of application it might serve, as Fig. 2 illustrates, broadcasting protocols are the best candidates for safety applications as they aim message dissemination in a certain area. On the other hand, geo cast routing, in which vehicles in a certain geographical area are targeted as receptions for a certain message and unicast routing which take place between two vehicles that are far away distance from each other, both are proper for comfort applications. This study however will only consider dissemination protocols that aim safety applications. Qualitative evaluation is considered in this study, but, it is worth to mention, for quantitative evaluations, performance metric should be well chosen in order to provide a certain level of functionally. Table 1 shows the targeted protocol characteristic and its definition along with the performance metric description uses to measure that characteristic.

METHODOLOGY

VANET routing protocols, candidates for safety applications: As indicated by Fig. 2, broadcasting is the most suitable communication mechanism for safety application; however it should be clear that, sometimes broadcasting is also used in the other type of routing like unicast and geocast in the route discovery phase (Li and Wang, 2007). The simplest way of broadcasting is the flooding method, in which all the nodes rebroadcast the message to all its neighbors except the one it sent the message. This mechanism provides high reach-ability. However, it is inefficient and wastes a significant amount of band width (Panichpapiboon and Pattara-Atikom, 2012). Mostly, broadcasting algorithms are aiming to efficiently utilize the bandwidth by decreasing the number of rebroadcasts, while still maintaining high reach-ability and low end-to-end delay. Thus the general framework of those protocols will be as follows, sender broadcasts the message. All the vehicles in its neighborhood receive and deliver the message to their upper layers. Then the minimum number of vehicles will be elected as next relays (forwarders) to deliver the message further in the network. Protocols that have been reviewed in this study are assuming the GPS service is available.

Criteria of the next relay selection: This is how a node in the neighborhood will be selected as the next relay to forward the broadcasted message further in the network. Types of criteria are discussed below.

The furthest node: In this criterion the node that is the furthest from the sender and still in its radio range is used as a relay for the message, this is reasonable, because all the nodes between the sender and this furthest node would be already received the broadcast message, obviously, calculation for this criterion will depend on the geographical position of the nodes in the network. This criterion is used to maximize the progress of the node and minimize the number of rebroadcast. Example protocols are Min-Te *et al*. (2000), Korkmaz *et al*. (2004), Fasolo *et al*. (2006), Mariyasagayam *et al*. (2007), Peksen and Acarman (2012) and Yoonyoung and Meejeong (2012).

The best link quality node: According to the real wireless channel conditions the furthest node would not always be the best node to relay the message. Thus, in this criterion the node with the best channel condition will be selected as the next forwarder. Calculations in this criterion may consider the amount of the received power and the distance between nodes. Protocols use this criterion is noticeably reliable; however, they may suffer from latency and the overall end-to-end delay. Taha and Hasan (2007) and Hao *et al*. (2008) are examples of protocols use such criteria.

Most demanding node: In this case, the reception of the message is prioritized according to the need of the nodes and the latest time for the message to be received by certain node, the nodes that are endangered should receive the message according to the latest time for them to successfully react. Usually graph problems and position of the nodes are used for the calculation of this criterion. These criteria will decrease the number of receptions and ensure the delivery of the message to the endanger node on time, anyhow considerable amount of calculation is required to determine the targeted nodes (Sebastian *et al*., 2010) uses this criteria.

Probability based forwarding: The nodes will forward the message with a certain probability assigned to them, thus the number of rebroadcasted messages will be reduced as all the nodes will not participate in the forwarding process. Protocols for this criterion will vary from assigning a predefined fixed value for forwarding probability to dynamically change this value according to vehicle location and density of the network (ALshaer and Horlait, 2005; Tonguz *et al*., 2007).

Backbone node: Some protocols assumed the existence of infrastructure in the network such as repeaters in #246, Korkmaz *et al*. (2004), or formed a special kind of network (e.g., Cluster network) as in Fan (2007). In which the message should always be delivered to certain node. In such cases the next relay will usually be a specified node (either mobile or fixed).

Each criterion type requires a certain amount of calculations, which will result in the selection of the node that fits well for certain criterion. Criteria calculations will differ according to the algorithm and it is recommended to keep those calculations as simple as possible in order to decrease the complexity of the algorithm, which in turn will affect the latency, hop time and end-to-end delay.

Broadcasting mechanisms for VANET: According to the method to initiate the communication, broadcasting protocols can be categorizes in to three categories as follows.

Neighborhood awareness broadcasting protocols: In neighborhood awareness approach, beacon messages are being exchanged to collect necessary information about vehicles in certain neighborhood (Tonguz *et al*., 2007; Hao *et al*., 2008; Sebastian *et al*., 2010; Peksen and Acarman, 2012). Beacon messages are short messages, contain information about the vehicle such as velocity, location, ID. Each vehicle will maintain a list of neighbors with all information that is necessary for next relay selection calculations. All protocols use this method are considered as not being very efficient in term of bandwidth, because regular beacon messages introduce a significant overhead to the network. Follows are examples of such protocols.

Track Detection (TRADE) protocol (Min-Te *et al*., 2000): This protocol aims to increase the reach-ability and efficient use of bandwidth. TRADE uses the furthest node as a next relay selection criterion. By the mean of beaconing, sender maintain a list includes the position information of its neighbors, these list has to be up dated regularly. Sender categorizes the neighbors vehicle according to their position and velocity vector in to one of three categorize: same road ahead, same road behind and different road, then selects the furthest node in the same road ahead and behind groups, while broadcasts to all vehicles in the different road group, this is done to increase the reach-ability, but for bandwidth sake the furthest vehicle in the different road group may be chosen. Sender then includes the ID of the targeted vehicles in the header of the message for each group. Although the criteria calculation is simple, yet, in addition to the overhead that is introduced by the beacons, considering the velocity vector lets the protocol affected by road structure. Performance evaluation, in term of bandwidth and reach-ability has been conducted and compared to flooding protocols, TRADE outperforms those protocols in term of bandwidth utilization and its performance is comparable to flooding protocols in term or reach-ability.

Media Access Control (MAC) protocol (Peksen and Acarman, 2012): MAC aims to avoid the long delay and broadcast storms by allowing the furthest node from the sender to be the next relay. Road inside the transmission range is divided into seven segments. The sender sends the message along with its position in the header. Receiver nodes will compare their position to the sender position to calculate their direction relative to the sender, only the nodes in the area bounded by the packet direction are allowed to participate in the next relay selection. Each participant node will checks its own neighbors list to determine which one is in the boundary area. Each participant node will compare its segment number with its neighbors (in boundary area) segments number to decide if itself is in the furthest segment from the sender. The node in the furthest segment from the sender will be elected as the next relay. If there is more than one node in the furthest segment, back off time that is proportional to the speed of the node will be assigned to each node. However, during the transmission of the packet by the elected relay, other nodes in the furthest segment will hold the message and wait as backup nodes, by the end of the transmission, backup nodes will check to compare the message in their buffer with the one they received from the relay, if message matched, the nodes will cancel the transmission operation. Packet reception ratio, hop delay and average overhead, have been evaluated through simulation for different node density with different packet sizes; while reception ratio and hop delay score reasonable values, the amount of the overhead really increases with the traffic density. These results have not been compared to any other protocol.

Reception Estimation Alarm Routing (REAR) protocol (Hao *et al*., 2008): This protocol uses the probability of reception as next reception selection criteria, so REAR does not relay the node that provides the largest progress on distance, it rather maximizes the receipt probability so as to extend the coverage distance and maintain quick propagation. By the mean of beaconing each node maintains neighbors list containing size and position information. Sender broadcasts the alarm message including message propagation direction and neighborhood list of the sender, only the nodes in propagation direction can participate in the relay node selection, participant nodes calculate its reception probability, each node will wait for a contention delay that is inversely proportional to its probability of reception. The node with the shortest contention delay will be elected as a relay and send the message further in the network. For more information on the probability of reception calculation refer to Hao *et al*. (2008). Simulation evaluation of this protocol shows its high reliability while its latency delay affects its performance.

Multicast routing for message dissemination protocol (Sebastian *et al*., 2010): This protocol uses most demanded node criteria to select the next relay, the purpose of the multicast routing is to disseminate warning messages to all in danger vehicles in a timely manner, this protocol adopts two strategies:

- Avoid unnecessary transmission by send the warning messages to the endanger vehicles only
- Minimize the transmission range using adaptive transmission power control

Anyhow, minimizing of the transmission range may result in more hops per message which might increase the end-to-end delay. Beaconing is used so the position of each neighbor node is already known. The problem of finding the routing path that will result in the minimum transmission area and minimum delay has been formulated as Delay Constrained Minimum Steiner Tree graph (D-CMST) problem, which is a well-known NP problem in literature with many existing algorithms to solve such problem.

Distributed Vehicular Broadcast (DV-CAST) protocol (Tonguz *et al*., 2007): DV-CAST aims to address the issues of broadcast storm while being able to distribute broadcast message to all intended receptions in addition to be robust against all possible traffic conditions, DV-CAST uses beacon information (Hello Messages) to determine local connectivity information (1 hop neighborhood topology). Therefore, according to local connectivity information a set of actions should be taken, following neighborhoods are considered in Tonguz *et al*. (2007) and Wisitpongphan *et al*. (2007).

Well connected neighborhood: In this case algorithm would apply one of following back off mechanisms:

- Weight p-Persistence Broadcasting, when a node receives the message for the first time, it will rebroadcast it with probabilityPij:

  $$Pij = Dij/R \tag{1}$$

  where, Dij is the distance between node i and node j and R is the radio range.
- Slotted 1 Persistence Broadcasting, when a node receives the message for the first time, it will rebroadcast it with probability 1 at the assigned time slot Ts, with the shortest waiting time is assigned to the furthest node form the sender.
- P-Presentence Broadcasting, when a node receives the message for the first time, it will rebroadcast it with probability P in the $Ts\ time\ slot$, with the shortest waiting time is assigned to the furthest node form the sender.

Sparely connected neighborhood: The vehicle is said to be in this category of neighborhood, if it is the last vehicle in the cluster, with at least one neighbor in the opposite direction road. In this case it will rebroadcast immediately, but if the last vehicle in the cluster does not have neighbors in the opposite direction it will carry the message until it gets connected to a vehicle in the opposite direction or the timer of the message expires.

Optimistic Adaptive Probabilistic Broadcast (OAPB) protocol (ALshaer and Horlait, 2005): OAPB also uses the hello messages to determine the local network topology, then this information is used by each vehicle to calculate its probability of forwarding ø according to following equation:

$$ø = \frac{p0+p1+p2}{3} \tag{2}$$

where, $p0$ is a function of the number of one hop neighbors, $p1$ is a function of the number of 2 hop neighbors and $p2$ is a set of 2 hop neighbors that can be reached through a particular one hop neighbor. Vehicles that have the same forwarding probabilities will be assigned different delays as follow:

$$\Delta(t) = \Delta(t)_{max} \times (1 - ø) + \delta \tag{3}$$

where,
$\Delta(t)_{max}$ = The maximum is delay time
δ = Random variable in milliseconds

Request for relay first broadcasting protocols: In this approach, the sender will have no idea about the position of its neighbors. First, the sender sends a request for a relay (known in the literature as RTS (Request-to-Send)) message containing its position and any other information that is needed by the certain criteria calculation, each node in the neighborhood receives the request and calculates based on the certain criteria to decide if it is the potential relay or if it is not, if it is the relay, it will send an acknowledgment to the sender (known in the literature as CTB (Clear-to-Broadcast)) and waits for the sender to send the broadcast message. This mechanism is known as a handshaking mechanism which might increase the end-to-end delay and consumes some of the bandwidth. Protocols (Korkmaz *et al*., 2004; Fasolo *et al*., 2006; Taha and Hasan, 2007) fall in this category.

Urban Multi-hop Broadcast (UMB) protocol (Korkmaz *et al*., 2004): UMB is designed to address the broadcast storm, hidden node and reliability problems. It uses the furthest node as a criteria selection. UMB, proposed approach for multi-hop broadcast in urban areas and can be applied to the highway scenario as well. Urban areas are crowded by tall building which cause line-of-sight problems, to address this issues, UMB supposed that all intersections are provided by repeaters, then the message should always be relayed to the repeater if it is available, otherwise a directional algorithm should be followed: road inside radio transmission range is divided into segments. When the node has a packet to send, it first sends RTS message containing its position, transmission duration and, propagation direction. Only nodes in the broadcast direction can participate in the relay node selection, once nodes in broadcast direction receive the RTS message, they start sending a jamming signal called black-burst, which its length duration L is proportional to the distance between the certain node and the sender as shown in Eq. (4):

$$L = \left\lfloor \frac{d}{R} \times N_{max} \right\rfloor \times S \quad (4)$$

where, d is the distance between the vehicle and the transmitter, R is transmission range, N_{max} is the number of segments inside transmission range and S is the time slot duration. After the jamming signal transmission, the node turns around and listens to the medium, if the medium is empty it means its jamming signal was the longest, thus it is the furthest from the sender so it transmits a control packet called CTB to the sender and this node will be elected as next relay. Otherwise, if the node finds the medium busy that means there are some other further nodes already received the RTS, so it does nothing and relegates the broadcast duty to the other vehicles. Upon a successful reception of CTB packet the source will send the warning message to the elected relay, the elected relay should send an ACK back to the sender after receiving the warning message. However, if the furthest segment contains more than one node, these nodes will try to send CTB at the same time and hence collision will occur, in this case, the segment will be further subdivided into more sub-segments and the nodes in the conflict should repeat the jamming signal sending process again until a successful transmission of CTB occurs.

Smart Broadcast (SB) (Fasolo *et al*., 2006): SB proposed new feature to avoid limitation of UMB,UMB wastes time to resolve the collision when it occurs, moreover UMB assigns the longest jamming signal to the next relay so that, next relay has to wait the longest time before start transmitting the signal. In SB sender first transmits RTS message containing its position, window size and, propagation direction. Only the nodes in broadcasting direction can participate in the relay node election, once the candidate nodes receive the RTS packet, they compare their location to the sender location and determine their sectors and then those nodes choose their waiting delay. For each sector there is a set waiting delays in such way that the vehicle in the furthest sector from the sender will be given the shorter waiting time. So for N_s sectors the waiting delays W_r for vehicles in sector r is randomly obtained from following set:

$$W_r = \{(r-1)cw, (r-1)cw + 1, \dots, rcw - 1\} \quad (5)$$

where, r is the sector number and cw is the duration of waiting delay, that will grantee to the vehicle in the farthest sector to be given the shortest delay. Random access with back off mechanism is adopted when collision occurs. Upon expiration of waiting time, the elected relay sends a CTB packet to the sender which itself start sending a data message. SB aims to maximize the progress of the message along the propagation line while minimizing the propagation delay.

Reliable Broadcasting of Life Safety Messages (RBLSM) protocol (Taha and Hasan, 2007): Using RTS and CTB control Packet, this protocol chooses the nearest node to the sender as next relay, so as it maximizes the probability of reception and increase the reliability of the network. The performance evaluation of this protocol is provided by the simulation and the only single hop latency is provided. However, Khan *et al*. (2011) evaluate the use of handshaking against Instant Broadcasting and they argue that due to the small payload of safety messages, handshaking may not be an advantageous since it may add more propagation delay to the message. And that instant broadcasting may achieve a better performance.

Immediate sending broadcasting protocols: The protocols that apply this approach intend to minimize the amount of the overhead and still maintain high reliability. The general framework of those protocols is as follows; the sender broadcasts the message immediately with its position and any other required information included in the header of the broadcasted message itself. The nodes in the sender neighborhood receive this message and select the next relay. The selected relay will immediately rebroadcast the message. Usually in this case, there would be a sort of acknowledgement to the sender, either by receiving back the rebroadcasted message, or by directly being acknowledged from the relay. If the sender failed to receive the acknowledgment, it will broadcast again after a certain period of time. Protocols (Mariyasagayam *et al*., 2007; Yoonyoung and Meejeong, 2012) adopt this mechanism.

Light Weight Reliable Broadcast Message Delivery (LW-RBMD) protocol (Yoonyoung and Meejeong, 2012): LW-RBMD intends to minimize the amount of

Table 2: Comparison of VANET broadcast protocols

Category	Next relay selection criterion	Protocol	Aim
Neighborhood awareness (beaconing)	Furthest node	TRADE	Increase reach-ability and efficiently use of bandwidth
		MAC	Maximize coverage and minimize latency
	The best link quality	REAR	Insure reliability, increase coverage area
	Most demanding	Multicast	Minimize the number of receptions, deliver message in a timely manner
	Probability based forwarding	DV-CAST	Minimize the number of forwarder, handle different traffic density
		OAPB	Minimize the number of forwarder, handle different traffic density
Request relay first (handshaking)	Furthest node	UMB	Minimize overhead and rebroadcasting storms, address hidden nodes issue
		SB	Minimize overhead and rebroadcasting storms increase propagation speed, decrease latency time
	Backbone node	UMB	Minimize overhead and rebroadcasting storms, address hidden nodes issue in urban areas
	Probability of reception	RBLSM	Increase reliability and area coverage
Immediate broadcast	Furthest node	LW-CAST	Minimize overhead increase coverage
		MHVB	Maximize coverage area, handle different traffic situations

the overhead and still maintain high reliability, this protocol relies neither on beacon nor on handshaking and still chooses the furthest node to be the next relay for the broadcast message, the sender will broadcast the message with the header contains its information (e.g., position), the receivers will calculate and the furthest node will rebroadcast first, the sender will listen to the rebroadcasted message and consider it as an acknowledgment. If the sender does not receive the acknowledgment after certain period of time, it will broadcast again. For the urban area the protocol allows the entire nodes that are in the intersection area to rebroadcast, which will increase the reach-ability.

Multi-Hop Vector Broadcasting (MHVB) protocol (Mariyasagayam *et al.*, 2007): Is also an Immediate Broadcasting algorithm uses the furthest node form the sender as next relay, when the node receives the packet it computes its distance from the sender and computes its waiting time, the vehicle that is the furthest from the sender will be given the shortest waiting time, when other vehicles receive the rebroadcast message they will cancel their retransmission. MHVB has a congestion detection mechanism, that, when the network is congested the vehicle will extend its broadcasting interval, the network is considered as congested if the number of neighbors for certain vehicle is above a certain threshold and its velocity is below a certain threshold. However a modified version (Mariyasagayam *et al.*, 2007) of this protocol considers not only the position of the forwarder but also the angle of the transmission sector, which result in flexible and directional transmission area. In the modified version, in case of congested network nodes at a distance farther than 200 m are made to transmit earlier than all other nodes in the network, which will extend distance and save network resource.

CONCLUSION

This study presents an overview of several VANET broadcasting protocols. Broadcasting algorithms are aiming to efficiently utilize the bandwidth by decreasing the number of rebroadcasts, while still maintaining high reach-ability and low end-to-end delay. As summarizes in Table 2, VANET broadcasting protocols have three methods to initiate the communication, either by:

- Sensing the neighborhood through exchanging the beacon messages among the nodes
- Handshaking mechanism
- Immediate broadcasting

There are many criteria to select the next relay; this study summarizes those criteria as following:

- The furthest node forms the sender
- The node with the best link quality
- Endanger nodes might be given high priority and been selected as next relay
- Each node might be given a certain probability to become next relay. Finally
- For protocols that assume infrastructure or cluster network, the next relay may be the fixed infrastructures node or the head of the cluster node

Performance evaluation for the reviewed protocols is evaluated through simulation. However, there is no general framework for theoretical evaluation of VANET protocols has been proposed, having such frame work will help in determining the performance limits of VANET Broadcasting protocols.

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