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Emergency Message Dissemination by Clustered Broadcasting Using Selective Reliable Broadcast in Vanets

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Abstract – Vehicular Ad hoc Network (VANET) is a subset of Mobile Ad hoc Network (MANET). VANET is a self-organized information system composed of vehicles (and possibly additional infrastructure) capable of short-range communication through the device called On Board Unit (OBU). There is a wide range of possible application areas of VANETs, including warning systems, collision avoidance/notification, autonomous vehicles, and traffic optimization.

VANETs rely heavily on broadcast transmission. When a vehicle rebroadcasts a message, it is highly likely that the neighboring vehicles have already received it, and these results in a large number of redundant messages. This affects inter-vehicle communications, since redundant rebroadcasts, contention and collisions can be largely increased as the number of vehicles increases. Broadcasting packets may lead to frequent contention and collisions in transmission among neighboring vehicles this problem is referred as the broadcast storm problem.

The main goal of Selective Reliable Broadcast protocol (SRB), is intended to limit the number of packet transmissions. Through an opportunistic vehicle selection, packets are retransmitted towards a next hop, in order to strongly reduce the number of forwarder vehicles, while preserving an acceptable level of QoS. SRB belongs to the class of broadcast protocols, as well as cluster-based approaches. It exploits the partitioning behavior, as typical from vehicular ad hoc networks, in order to automatically detect vehicular clusters, intended as "zones of interest". Packets will be then forwarded only to selected vehicles, opportunistically elected as cluster-heads. SRB performances have been assessed in different vehicular scenarios, mostly realistic environments, such as highway scenarios.

Index Terms – Broadcast, vehicular ad hoc network (VANET), Cluster, Broadcast storm problem.

1. INTRODUCTION

Vehicular Ad hoc Networks (VANETs) are emerging as the preferred network design for Intelligent Transportation Systems (ITS), providing inter-vehicular short range communications, for the support of Internet access and safety applications.

VANETs are a particular class of Mobile Ad-hoc Networks (MANETs), showing typical characteristics. Indeed, VANETs consist of mostly highly mobile nodes moving along the same or opposite directions (i.e., vehicles), forming clusters. Vehicle-to-vehicle (V2V) communications are supported due to "smart" vehicles, equipped with On-Board Unit with multi-Network Interface Cards (NICs), such as IEEE 802.11p, WiMax, Long Term Evolution, and also Global Navigation Satellite System (GNSS) receiver. However, communications among vehicles belonging to different clusters are not always guaranteed, due to connectivity disruptions caused by quick topology network changes, different and variable vehicle speed, and sparse or totally disconnected scenarios. Moreover, also the market penetration rate can hinder inter-vehicular communications: unequipped vehicles physically occupy space and then alter the spatial distribution of equipped vehicles, and their mobility. On the other side, connectivity improves as the market penetration increases, since it directly translates in an increasing probability of finding a neighboring vehicle that forwards messages.

Inter-vehicle communications are expected to significantly improve transportation safety and mobility on the road. Several applications of inter-vehicle communications have been identified, from safety and warning applications, up to traffic control and driver assistance applications [7, 18].

In this vision, most applications targeting VANETs rely heavily on broadcast transmissions, such as to discover neighboring vehicles, as well as to disseminate traffic-related information to all the reachable vehicles within a certain geographical area i.e., mostly in general for context-aware applications. On the other side, broadcasting packets may lead to frequent contentions and collisions, due to redundant transmissions among vehicles in dense network topologies.

This problem is referred to as the broadcast storm problem. It affects inter-vehicle communications, since redundant rebroadcasts, contentions and collisions can be largely increased; when a vehicle rebroadcast a message, it is highly likely that the neighboring vehicles have already received it, and this results in a large number of redundant messages and replica.

In a traditional MANET environment, multiple solutions have been proposed in order to alleviate the broadcast storm effect, but only a few solutions have been addressed to the VANET context [3]. Most of recent research works have focused on analyzing VANETs as well-connected networks, providing high vehicular traffic density. As vehicles in close proximity detect the same dangerous situation, they will inevitably broadcast messages relating to the same event, leading to a dramatically excessive message redundancy. In such scenarios, broadcast suppression solutions have to be considered. In contrast, in low vehicular traffic density environments, with a sparse Road Side Units (RSUs) settling and a low market penetration rate, vehicular connectivity results intermittent, poor, and short-lived [17] . In this context, the design of reliable and efficient routing protocols for supporting highly diverse, and mainly intermittently connected vehicular network topologies, is still a challenge. Hybrid solutions based on both V2V, and vehicle-to-infrastructure (V2I) communications, result as a viable alternative to routing protocols that exploit the V2V paradigm only [16].

In this paper, we present a cluster-based broadcast technique for safety applications in VANETs. Our approach is called Selective Reliable Broadcast (SRB), and relies on the opportunistic cluster selection in order to reduce the broadcast storm effect: SRB selects only one vehicle within a cluster namely, a cluster-head in order to efficiently rebroadcast emergency and control messages. SRB technique is then able to detect the well-known car platoons, which cause traffic congestions and delays, in a fast way and with low overhead, in order to eventually recommend alternative paths to other vehicles. As a result, SRB limits the number of transmissions but preserves good network performance.

2. RELATED WORK

In this section we give an overview of previous contributions in broadcast protocols for VANETs, particularly focusing on cluster-based approaches. Within the discussion, we clarify the paper objective and then introduce our proposed approach.

Reliable protocols use three methods i.e.,(i) rebroadcasting, where the transmitter node retransmits the same message for many times, (ii) selective ACK, where the transmitter requires ACK from a small set of the neighbors, and (iii) changing parameters, where the transmitter changes transmission parameters according to the expected state of the network.

The problem statement for reliable protocols is to design a protocol that can deliver a message from a single source to every node in the own transmission range with the highest possible reliability and minimum delay. Successful message dissemination in VANETs needs an efficient decision mechanism in order to maximize reliability, and keep the overhead low. The decision criterion about when and how a safety message should be delivered or repeated is an open issue.

Given the requirements of safety applications (i.e., low delay and effective reliability), and the limitations of vehicular communications (i.e., short-lived connectivity links), selective broadcast or multicast strategies seem more applicable than either unicast routing or flooding. In fact, the latter generates a high overhead without increasing the success rate substantially [4]. Several solutions have been made to introduce intelligence to the basic broadcast concept, and make it more selective and, thus, more efficient in its resource usage.

A largely common assumption in connectivity models for VANETs is that a vehicular network is partitioned into a number of clusters [12, 19]; vehicles within a partition can communicate either directly or through multiple hops among each other, but no direct connection exists between partitions, as well depicted in Fig. 1. A particular class of routing protocols namely, the cluster-based approaches uses this assumption by exploiting clusters formation [9].

Based on geographical locations, directions of movement, speed and many other metrics, vehicles can group into different clusters. Clustering enhances effective broadcasting and relaying of messages, while reducing the overhead associated with signal-ing and the number of unnecessary message replica. This is due since links among vehicles within the same cluster tend to be more stable, although dynamic topology changes can occur. Leveraging on this issue, an efficient clustering should be based on adequate metrics and should take into account the frequent topology changes. The formation of clusters and the selection of the cluster-head (i.e., a vehicle leader within the cluster, responsible for intra and inter-cluster communications) are strongly affected by the high mobility dynamic cluster formation process. Ni et al. (1999) [14] consider each cluster comprised of three node types i.e., head, gateway and member. The gateway nodes are those who connect to the gateway nodes in other clusters, while the cluster-head is a node whose transmission radius can reach everyone in the same cluster. Finally, members are those who do not belong in either head or gateway group. When a gateway node receives a message from other clusters, it will rebroadcast the message that will be received, and then further retransmitted, by the cluster-head. Although this cluster architecture is correct [14], the authors did not specify the procedure for the cluster-head election.

Fasolo et al. (2006) [5] propose a Smart Broadcast protocol, which exploits vehicles' positions. The proposed technique assumes that the vehicular network is partitioned in adjacent sectors and that vehicles are able to estimate their own position and, therefore, the sector they belong to. The Smart Broadcast technique considers a contention resolution procedure to elect the relay nodes. Although this technique seems very efficient, it has not been validated in terms of network performance and system overhead. Another work that considers both information on vehicles' position, and the cluster formation, is presented by Luo et al. (2010)[13]. Their approach is a cluster-based routing protocol and the basic idea is to divide the geographic area into foursquare grids, where a vehicle is elected as the cluster-head to route data packets across nearby grids. Also this technique needs to be validated via simulation results. Finally, in [15] propose an RSU-assisted cluster head selection, by exploiting V2I connectivity, whenever inter-vehicle communications are not available.

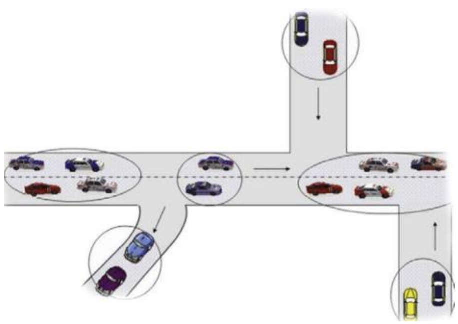

Fig.1 Schematic of several vehicle clusters. Vehicles belonging to the same cluster can communicate each other, while due to the gaps among consecutive clusters, no inter-cluster communications are available.

In all the previous works, mobility aspects have not been considered, while it is noticeable that the cluster selection process is particularly affected by vehicle mobility and cluster stability. Benslimane et al. (2011) [2] consider the cluster formation on the basis of the direction of vehicles movement, the Received Signal Strength (RSS), and the inter-vehicular distance. In this envision, the directional antenna-based Medium Access Control (MAC) protocols are exploited to accurately group vehicles on the basis of the direction of their movements and the transmission angles. Gunter et al. (2007) [6] take into account mobility during cluster collision, and a cluster-head vehicle is that one with the lowest relative mobility and closest proximity to its neighbors. Alterna-tively, Kayis and Acarman (2007) [10] classify nodes into speed groups, so that nodes belonging to the same speed group will be in the same cluster. Koyamparambil Mammu et al. (2013) [11] propose a cluster-based MAC protocol able to form stable clusters, and elect stable CHs, while achieving high reliability and low delay. This is achieved by considering vehicles in the VANETs are divided into different clusters based on their position, direction of movement, lanes, and speeds. Also,[8] present a CH selection technique, based on the relative speed, and distance of cluster heads from vehicles within their neighborhood. Finally, a well-known mobility-based clustering technique is MOBIC [1], which considers an aggregate local mobility metric as the basis for cluster formation: the node with the smallest variance of relative mobility to its neighbors is elected as the cluster-head.

In this work, we present SRB, a reliable cluster-based routing protocol that is expected to minimize the number of rebroadcast messages. SRB considers the cluster selection process, and the cluster-head election, by exploiting the inter-vehicle distance and the time delay. Via simulation results, SRB results in an efficient method to detect clusters and alleviate the broadcast storm problem.

3. PROPOSED WORK

A selective reliable broadcast protocol (SRB) is expect to minimize the number of rebroadcast message by limit the number of packet transmission. Through an opportunistic vehicle selection, packets are retransmitted towards a next hop, in order to strongly reduce the number of forwarder vehicles. This can be done by detecting the cluster of vehicles in a fast and efficient way and elect one as CH vehicle for each cluster detected.

A. Mobility Model Generator

The most important parameters in simulating ad-hoc networks is the node mobility. It's important to use real world mobility model so that the results from the simulation correctly reflect the real-world performance of a VANET, example a vehicle node is typically constrained to streets which are separated by buildings, trees or other objects. Such obstructions often increase the average distance between nodes as compared to an open-field environment.

We will deploy a tool MOVE (Mobility Model Generator for Vehicular networks) to which will provide facility for the users to generate real world mobility models for VANET simulations. MOVE tool is built on top of an open source micro-traffic simulator SUMO (Simulation of Urban MObility). The output of MOVE is a mobility trace file that contains information of real-world vehicle movements which can be used by NS-2 or Qualnet. MOVE provides a set of GUI that allows the user to quickly generate real-world simulation scenarios without any simulation scripts.

MOVE consists of two main components: the Map Editor and the Vehicle Movement Editor, The Map Editor is used to create the road topology. Currently we have implemented three different ways to create the roadmap– the map can be manually created by users, generated automatically, or imported from existing real world maps. The Vehicle Movement Editor allows user to specify the trips of vehicles and the route that each vehicle will take for one particular trip. The output of MOVE is a mobility trace, generated based on the information users input in the Map Editor and the Vehicle Movement Editor, which can be immediately used by a simulation tool such as ns-2 to simulate realistic vehicle movements.

- MAP Editor *:* In MOVE, the road map can be generated manually, automatically or imported from a real world map. Manual generation of the map requires inputs of two types of information, nodes and edges. A ”node” is one particular point on the map which can be either a junction or the dead end of the roads. Furthermore, the junction nodes can be either normal road junctions or traffic lights. The edge is the road that connects two points (nodes) on a map. The attributes associated with an edge include speed limit, number of lanes the road priority and the road length. The map can also be generated automatically without any user input. Three types of random maps are currently available: grid, spider and random networks. There are some parameters associated with different types of random maps such as number of grids and the number of spider arms and circles. Finally, one can also generate a realistic map by importing real world maps from publicly available database.
- Vehicle Movement Editor: The movements of vehicles can be generated automatically or manually using the Vehicle Movement Editor. The Vehicle Movement Editor allows users to specify several properties of vehicle routes including number of vehicles in a particular route, vehicle departure time, origin and destination of the vehicle, duration of the trip, vehicle speed. In addition, user can define the probability of turning to different directions at each junction (e.g. 0.5 to turn left, 0.3 to turn right and 0.2 to go straight) in the editor.

B. RTB and CTB clearance

Before sending Request-To-Broadcast (RTB) and Clear-To-Broadcast (CTB) message, network are partition into a sector through which the message are propagate along the transmission direction from the source vehicle and are identified as portion of a circle. The sector size varies as a dynamic process, iteratively hop by hop, depending on the transmission direction from each transmitting vehicle. The i_{th} sector is identified by an angle $\alpha_i(h)$, where h is the index of current hop. Initially, in the h=1 hop, there is a unique sector that includes the source vehicle’s transmission range i.e., corresponding to an angle α(h)=360. On the next hops (i.e., when h=1), n sectors are identified, each one associated to the n_{th} forwarder vehicle, by the second hop (i.e., h>1) we consider that the i_{th} forwarder vehicle has an angle corresponding to its forward or backward transmission range, so that $\alpha_i(h>1)=180$. In Fig.2 depicts the sector identification in the first and second hops.

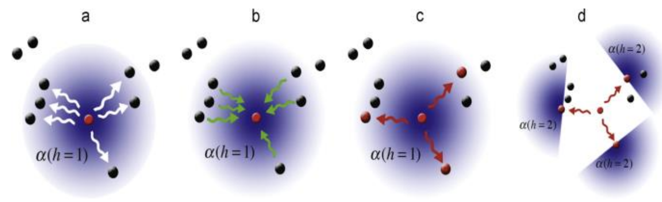

Fig.2 Sector Formation

The red and black points are respectively the source and neighboring vehicles, while the blue area represents the transmission range of one vehicle. In the first hop, during (a) RTB transmission, (b) CTB transmission, and (c) cluster-head selection, α(h=1)=360. By the second hop, (d) the message propagation is only backward or forward, and then α(h=2)=180.

SRB consider a contention procedure and cluster detection mechanism as follows

A source vehicle transmits a RTB control message to all the neighboring vehicles in the transmission range. After receiving an RTB message, the vehicle compute their distance from the source vehicle Than the vehicle send back to the source as CTB packet, containing the vehicle ID and its distance from the source. After receiving a valid CTB packet, vehicle exit the contention phase.

C. Cluster detection and CH election

Once the source vehicle receives information on the ID and the distance from its nearby vehicles. By measuring the Direction of Arrival (DoA) of the CTB messages, the source vehicle is able to calculate all the mutual inter-vehicle distances among its nearby vehicles. If the distance between each couple of nearby vehicles is lower than a threshold value (i.e., D_{min}), the two vehicles will be considered belonging to the same cluster as shown in Fig.3 The choice of D_{min} influences the number of clusters identified: the higher the distance threshold, the higher the number of vehicles in each cluster.

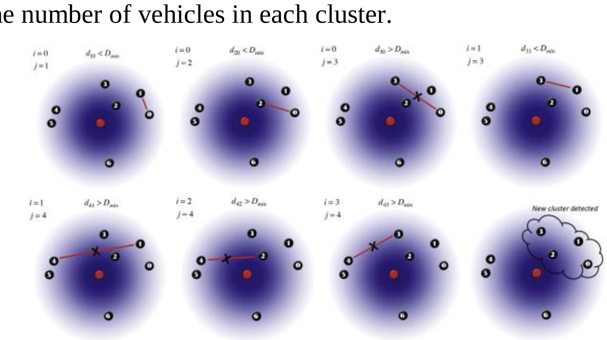

Fig.3 Cluster Detection Mechanism

After detecting multiple clusters, the source vehicle elects the furthest vehicle inside each cluster as the CH, and transmits a data message only to such vehicle. Upon receiving the data message, each CH will become the message source for the next contention phase, and the SRB method is repeated for the next hops. In Fig.4 depicts the main phases of SRB technique for a forward data transmission along the vehicular grid. Once the CH vehicles are identified, they will forward message according to SRB technique.

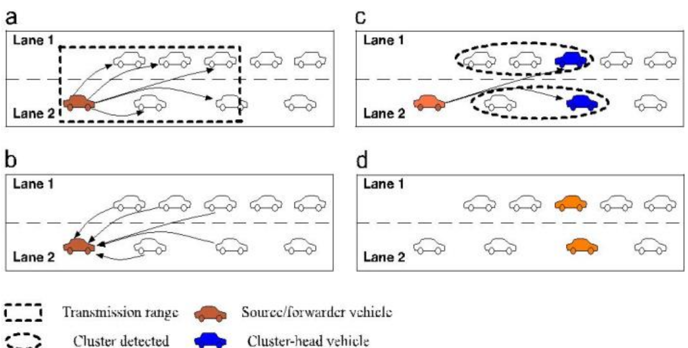

Fig.4 Main phases of SRB technique: (a) RTB transmission, (b) CTB transmission, (c) Cluster detection and CH election, and (d) message propagation.

PARAMETERS	VALUE
1. Channel	Wireless channel
2. Antenna	Omni/Directional Antenna
3. MAC Protocol	IEEE 802.11
4. Routing Protocol	AODV
5. No. of Nodes	100

Table I
Simulation Parameters and Values

The design and implementation of the cluster detection mechanism in the SRB algorithm follows the steps of the method ClusterDetection ( ), Let us define:

- **veh**, as a m _ 1 array whose elements are the vehicles' IDs reachable by the transmitter vehicle. The array is sorted according to the angles formed by the DoA of the messages sent to the transmitter;
- **sels**, as a dynamic array, initially null, whose elements are the forwarder vehicles' IDs (i.e., the selected vehicles for next hop forwarding).

During the initialization, we define three indexes i.e., i and j, used to calculate the inter-vehicle distances, and k is the index associated to the array of forwarders (i.e., **sels**). The method ClusterDetection has a 'while' command, which considers three different cases:

- Case 1: the index j is greater than the number of elements comprised in **veh**;
- Case 2: the distance between a couple of vehicles is less than D_{min} [m] i.e., the minimum distance within the cluster;
- Case 3: the distance between a couple of vehicles is greater than D_{min} [m].

The calculus of distances $v_{i,j}$ between two neighboring vehicles is done by means of the method distance (v_i, v_j), and starts for a null value of angle. This means that the first comparison will be between the vehicle with index 0 and the vehicle with index 1, where 1 and 0 are the positions of elements of the array.

4. PERFORMANCE ANALYSIS

A. simulation environment

The simulation environment used for the proposed work is given in the following Table I. It describes the various parameters used for the simulation.

B. performance parameters

The performance analysis of the VANET based on Selective reliable broadcast is done with the help of the parameter.

- *Throughput:* Throughput denotes that the correct cluster detection has occurred if the amount of packet exchange has increased significantly. In Fig.5 shows throughput experienced by vehicles moving in highway scenario. The throughput of SRB approach increases by 15.38% when compare to CDP approach.

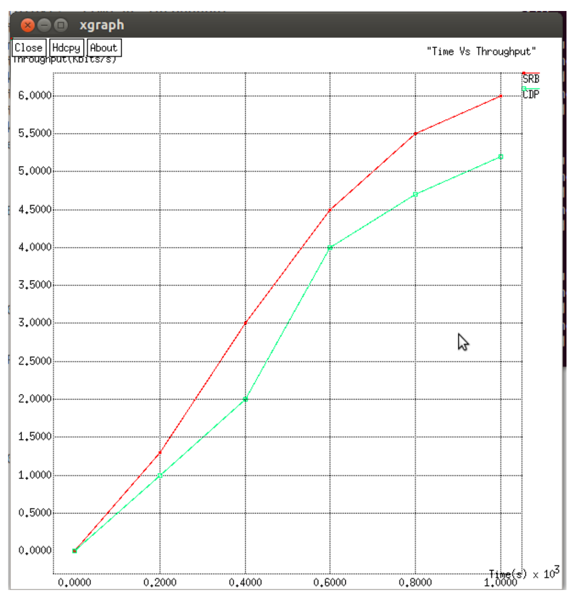

Fig.5 Throughput

- *Packet Delivery Ratio:* Packet Delivery Ratio is defined as the ratio of number of packets successfully received and number of packets transmitted. It increases due to successful transmission of packets by the intermediate nodes. In Fig. 6 shows that the SRB approach is increases by 18.75% when compared to CDP approach.

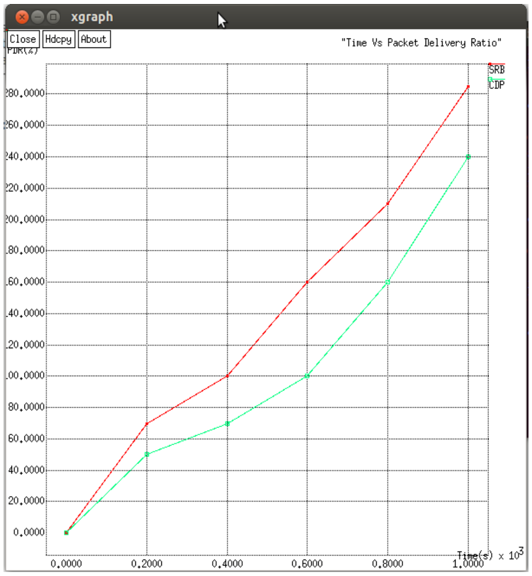

Fig.6 Packet Delivery Ratio

5. CONCLUSION AND FUTURE WORK

In SRB, aims to alleviate the broadcast storm problem by selectively broadcast the message within their own transmission range that will reduce the network overload and limit the message duplication SRB is particularly effective for safety applications: it relies on cluster-based routing protocols, as well as exploits the vehicles positions, in order to detect traffic congestions in a fast way and with low overhead. Only a limited number of vehicles are elected as cluster-heads to forward messages. SRB has been validated through the simulation, of highway scenarios it works efficiently by means of a faster detection of congested area. In future it can be extended for urban scenarios.

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