An Efficient Emergency Message Dissemination in a Vehicular Ad Hoc Network

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ABSTRACT: *VANET has become an attractive domain of research because it has tremendous potential to improve safety and comfort on roads. One key usage of VANET is to support vehicle safety applications like dissemination of emergency messages. Due to inherent characteristics of vehicular ad hoc networks and the emergency of the messages, most of developed applications are based on multi hop broadcasting. The most basic strategy is called flooding. This strategy is well studied in the context of mobile ad hoc networks and has been shown it causes contentions, collisions and redundancy, well known as the 'broadcast storm problem'. The majority of existing solutions focuses on decreasing the number of relay nodes and discards the use of unicast messages. In this paper we study a new strategy that combines the use of unicast and broadcast modes at the same time. Simulation results show that the proposed protocol achieves low latency in delivering emergency warnings in spite of the use of unicast messages. These results have been enhanced by modifying the MAC layer protocol parameters.*

Keywords: Dissemination, Vehicular Ad Hoc Networks, Vehicle to Vehicle Communication, Unicast Mode, Broadcast Mode, Multi-Hop

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1. Introduction

Advances in wireless technologies are opening up exciting possibilities for the future of vehicular ad hoc networks that will have a positive impact on the quality of the driving: more security and more comfort thanks to the various services offered. Vehicular ad hoc networks (VANETS) are emerging as a particular type of mobile ad hoc networks (MANETS) formed by moving vehicles equipped with wireless interfaces which allow them to communicate during their travel. Both of MANETS and VANETS use the same wireless technology. But VANETS are different because of many features. The most important, the topology and the node movement are constrained by roads, signposts and obstacles like buildings. So, existing communication protocols in MANETS cannot be used for VANETS. Recent research efforts include standardization, routing, Quality of Service (QoS), security and safety applications to improve vehicle and road safety, traffic efficiency and comfort to passengers. Our work focuses on safety applications especially dissemination which target to distribute pertinent information about traffic status to let conductors be aware of the dangers.

The existing solutions [4, 9, 10, 11, 12, 13] use multi-hop broadcast strategy to access to a great number of vehicles in dangerous area with acceptable delivery delays. Many ideas are proposed to overcome the broadcast storm problem [5] by decreasing the number of vehicles relayed to rebroadcast the emergency message: One relay vehicle would make the best strategy. We can classify the dissemination protocols in VANETS into two classes: The first class is composed by the topology-based protocols. These protocols maintain locally a neighborhood table which is actualized by the periodic "*hello*" messages. In these protocols the relay node is designated by the sender. The second class is composed by the time-based protocols. In these protocols, the sender has no knowledge about its environment, it broadcasts its alert. When receiving the alert message, all the nodes wait duration of time that can be a random value or calculated by using functions with parameters like the latency and the distance separating the sender and the receiver. During the waiting time, if the receiver does not receive again the same message, it recognizes itself it has to rebroadcast the alert. All other nodes stop their waiting just when receiving again the same message. We think that this strategy maintains the redundancy problem because the broadcast transmission is performed every one hop so that the area between two relay nodes is covered at least twice.

Our approach uses the unicat mode to disseminate the emergency message as far as possible on the road in a multi-hop way. Each hop is at most equal to the nodes transmission range. Broadcasts are performed every two hops to make all vehicles informed.

The rest of the paper is organized as follow. In section 2, we present the related works. In section 3, we describe the 'UUB' protocol strategy and the integration of the prioritization mechanism. In section 4, we present simulation results, and, we conclude the paper in section 5.

2. Related work

Recently, several dissemination protocols emerged. The methods are differentiated according to the type of the applications. The comfort applications are varied, for example, a request about the availability of a product or about a place in a car park. In these applications, the peer to peer communication mode is the most used. One of the approaches adopted is the epidemic approach [2] inspired from the epidemiology domain. It is based on a simple principle. Any vehicle carrying information sends it to any vehicle that enters its communication range. In [1], the proposed solution differs by taking into account the VANETS characteristics and the road parameters like speed limits and traffic density.

On the other hand, emergency applications aim to reduce the probability and severity of accidents on the roads by providing alert messages to vehicles located in dangerous region. An emergency message is characterized by its location, its zone of relevance and its validity duration. So, emergency message dissemination protocol must ensure these spatial and temporal constraints. Indeed, all vehicles close to the incident location have to be advised in time, so that they have the possibility to act consequently.

In emergency applications, the multi hop broadcast mode is the most used. The simplest way to perform the dissemination is by simple flooding: When a node receives a broadcast message for the first time, it rebroadcasts it immediately. This strategy causes collision, contention and redundancy problems well known as "Broadcast storm problem" [5]. In [5], the broadcast storm problem was studied and analyzed in mobile ad hoc networks. There are five proposed schemes to face this problem: The probabilistic scheme, the Counter-based scheme, the distance-based scheme, the location-based scheme, and, the cluster-based scheme. All these schemes converge on the idea to prevent certain vehicles having received the message to rebroadcast it.

In vehicular ad hoc networks, alert dissemination protocols can be divided according to the way that relay nodes are selected, into two classes:

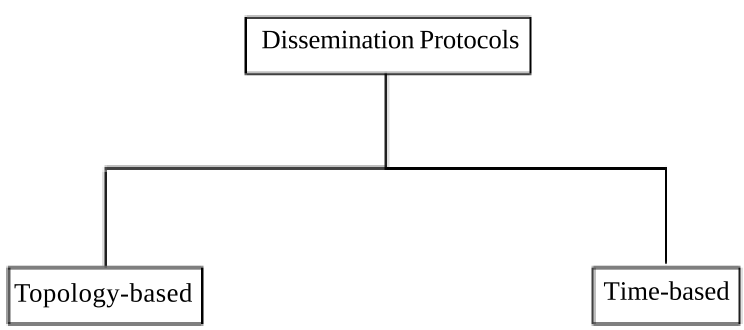

Figure 1. Dissemination Protocols Classification

In the first class [4,13], the use of periodic "*hello*" messages allows the sender to know its neighborhood, so it selects among its neighbors the farthest one in the opposite direction of the road traffic and designates it as a relay. This strategy had been criticized by the fact that the "hello" messages increase the broadcast storm problem. We think that we cannot avoid using the "*hello*" message because on one hand the information brought by these messages is very important (position, direction, speed, status of neighboring nodes) and on the other hand several protocols like routing are topology-based. So, we have to find solutions to keep this mode of communication and to eliminate its effects.

In the second class [9,10,11,12,15], the receivers of the alert wait a waiting time "*WT*" to decide whether they have to rebroadcast the message. In the best case one node rebroadcasts the message. Other nodes, when receiving the message again, stop their waiting.

In [10, 11, 12], the value of the "*WT*" is conversely proportional to the distance between the sender and the receiver. So, the farthest node in the transmission range of the sender is always the relay node.

The solution proposed in [15] is similar to [10]. However, in [15] a relay node can choose its waiting time within a given time range so that it can reduce its waiting time. This means that the farthest node from the sender is not necessary the relay node. This strategy can improve the dissemination delay, but causes more redundancies.

Several protocols [6, 7, 8, 14] proposed solutions at the MAC layer their goal is to define an access method to make the dissemination strategies more sure. The RTB/CTB mechanism proposed in [7] has been shown by means of simulation that the directional mode data dissemination mechanism used in UMB outperforms its peers [18].

All the above presented solutions use the broadcast mode at every one hop. So all vehicles located between the sender and the receiver, receive the message at least twice causing redundancy. In [17], the proposed solution uses the broadcast and the unicast modes at the same time. A unicast message is forwarded from a relay vehicle to the next relay in the opposite of the vehicles direction. The distance between two relay nodes is at most equal to vehicles transmission range. When a node receives a unicast message, it first forwards it to the next relay and decides whether it has to broadcast it. This protocol suffers from collisions which occur between messages and beacons. Our approach is based on the use of the EDCA (Enhanced Distributed Channel Access) mechanism which is specified to provide differentiation service and prioritization mechanism at IEEE 802.11e MAC layer [16, 21]. We differentiate messages by their priority so that the data messages are assigned to a high priority class and the beacon messages are assigned to a low priority class.

3. Assumptions and protocol description

In this section, we give the assumptions and we present our protocol strategy:

3.1 Assumptions

We assume that vehicles use wireless communication through omni directional radio antennas of transmission range *R*. Each vehicle is equipped with a device enabling it to obtain its geographical location in a current time, like GPS device, and, a preloaded digital map, which provides general information about roads. The vehicles periodically exchange their own physical location, moving velocity and direction information enclosed in their periodic beacon messages. This information are maintained and updated locally to be used to calculate the distance between vehicles. Emergency messages are sent in the opposite of vehicles direction. We use EDCA (Enhanced Distributed Channel Access) mechanism at the IEEE 802.11e MAC layer to provide prioritization between messages.

3.2 Dissemination strategy

An emergency message can be generated by a vehicle (called initiator) in a dangerous situation. For example, in case of an accident, a vehicle can recognize it is in a dangerous situation through sensors that are able to detect internal events like airbag ignition, it can also sense a danger around it by using sensors and cameras. Omni antennas used in wireless transmission allow a mobile node to transmit its signal all around it within a transmission range *R*.

Nowadays, dissemination protocols have improved their performances by decreasing the effects of storm problem. However, the fact that the message is broadcasted at every one hop causes unavoidable redundancy in the zone between two relay vehicles. *Figure 2* shows zones of redundancy represented by the intersection between two areas covered by the broadcast messages respectively performed by relay nodes *A*, *B*, *C* and *D*.

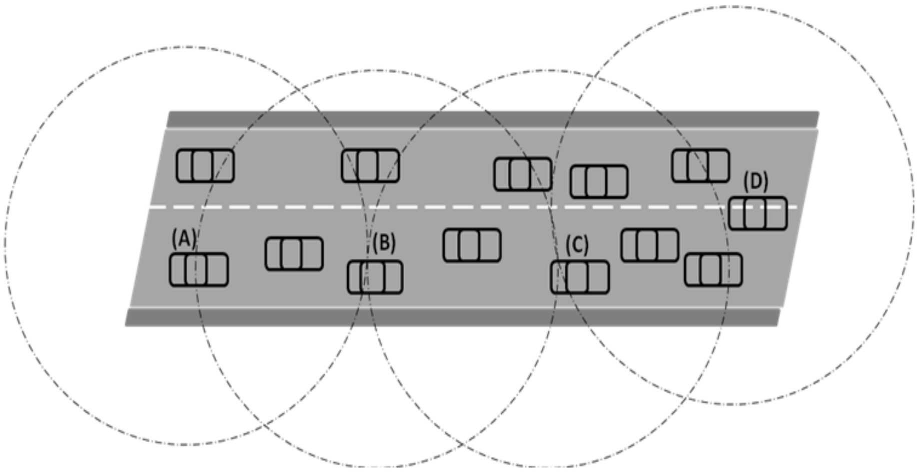

Figure 2. Broadcasting at every one hop causes redundancy

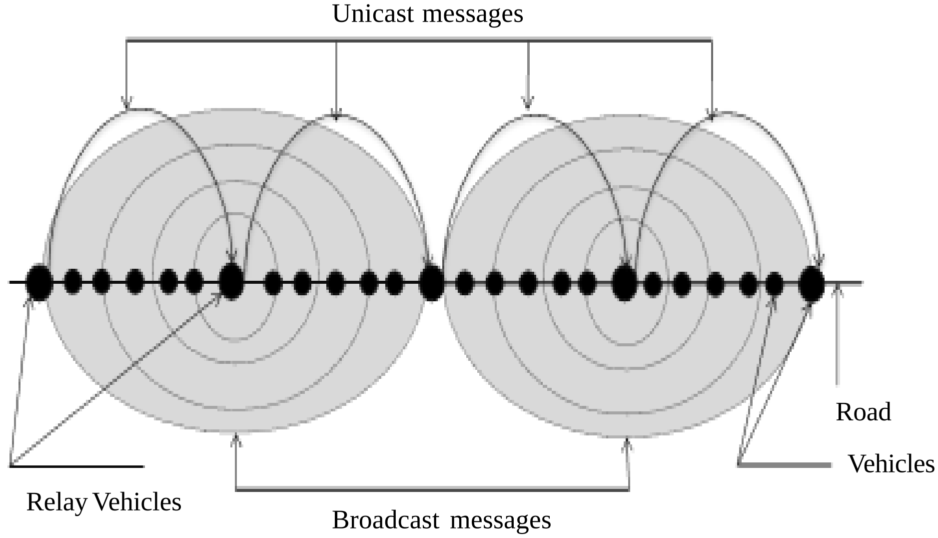

Figure 3. General Scheme of the Dissemination

To the best of our knowledge, existing protocols discarded the use of the unicast mode because it needs more time than the broadcast mode. However, it is more reliable [20, 21] and we can show using simulation that the latency is not affected. In our approach, we use the unicast mode between relay nodes to propagate the information as far as necessary while the broadcast mode is used every two hops to inform nodes that there is an emergency situation. So, the redundancy zone will be eliminated as it is shown in *figure 3*.

In this section we present our EEMD Protocol design [17] that performs dissemination of an emergency message according to our approach.

3.2.1 The 'EEMD' Protocol

The initiator selects among its neighbors behind it, the farthest one, and, sends it a unicast packet data that contains the emergency message. The farthest node is considered as a relay. It first transmits a unicast message to the farthest neighbor behind it within its transmission range to ask it to forward the message like the initiator and then broadcasts the message. So, there are two unicast messages followed by one broadcast message to reach two hops.

In *figure 4*, when vehicle B receives the vehicle A packet, it first sends a packet which contains the emergency message to vehicle C in a unicast mode, and then broadcasts it. Vehicle C sends immediately its unicast message to the farthest vehicle from it in its vicinity (vehicle D) which acts like vehicle B.

Considering figure 3, supposing that the broadcast performed by vehicle B failed, In this case vehicle A resends its packet to vehicle B which is asked to perform only the broadcast. At the same time, vehicle C has already sent its packet to vehicle D which acts like vehicle B. Consequently, the propagation time of emergency message is not delayed.

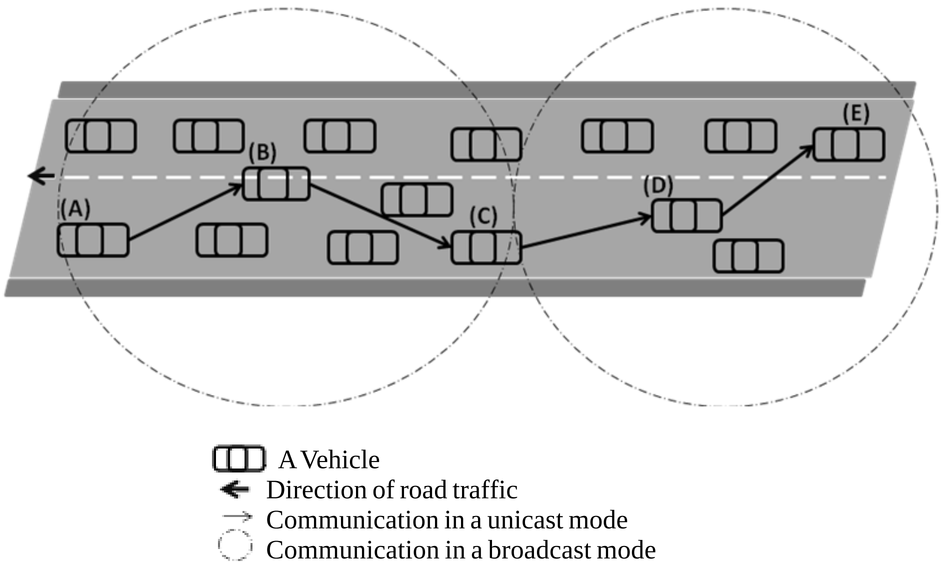

Figure 4. The dissemination scheme on a section of road

So, the proposed protocol has two characteristics:

• On one hand, we can see that there are two processes in progress at the same time: the unicat and the broadcast transmissions,

• On the other hand, the fail of a broadcast performed by one relay node does not affect the following ones anymore. So, the dissemination process continues its track while the problem can be treated locally by rending the message.

3.2.2 Message form and algorihme

We define three types of messages: Two unicast messages {U1, U2} and one broadcast {B}. The dissemination process behaves differently when a node receives any one of these messages:

• **Message description**

U1 =< id_mess,contents>

U2 =< id_mess,contents>

B =< id_mess,contents,source>

• **When U1 is received by a node i**

it sends a unicast message U2 to the farthest neighbor,

it sends the broadcast message B

• **when U2 is received by a node i**

it sends a unicast message U1 to the farthest neighbor,

• **when B is received by a node i**

it keeps itself informed.

3.2.3 Network fragmentation

The proposed protocol distinguishes two types of relay nodes. The first one has only to forward the received message to its farthest neighbor. The second type has furthermore, to broadcast the message. When a relay node has no contact behind it (this situation is commonly known as fragmentation), it waits until a new contact enters its transmission range and sends a unicast message to it to inform it that it must act as an initiator node. If the relay belongs to the second type, it first sends the message in a broadcast mode to inform all vehicles above, and then waits a new contact.

3.2.4 Messages Prioritization

The activation of beacon messages at the MAC layer can causes dramatically a large number of collisions between data and beacon messages. Due to the emergency of our application, we adopt the EDCA (Enhanced Distributed Channel Access) protocol which is specified to provide differentiation service and prioritization mechanism at IEEE 802.11e MAC layer [21]. We differentiate messages by their priority so that the data messages are assigned to a high priority class and the beacon messages are assigned to a low priority class.

4. Simulation

Difficulty to have a real experimentation platform makes simulation essential to evaluate the performance of protocols. In this simulation, we compared our protocol with a time-base protocol [10].

The parameters of our simulation are listed in *table 1*. Performance evaluation of the protocols was conducted using the widely adopted Network Simulator NS2 [19]. We used various mobility scenarios generated with the MOVE generator [19] by varying the vehicles densities. Vehicles move in the same direction on a road of 10 km composed of 4 lanes. The maximum vehicles speed is 30 m/s.

Parameter	Value
Mac Layer	IEEE 802.11 / IEEE 802.11e with EDCA mechanism
Transmission range	250m
Beacon interval	1sec
Road length	10 km
Number of lanes	4
Traffic density	2, 4, 6 and 8 vehicles/km/lane
Maximum vehicle velocity	30 m/s

Table 1. Simulation setup

The simulation results show that the delivery rate of the three protocols reach 100% for all mobility scenarios with none or partial fragmentation. So, the simulation shows that EEMD protocol is reliable.

On the following, the EEMD protocol without prioritization mechanism is denoted EEMD and the EEMD protocol with prioritization mechanism is denoted EEMD+.
The mean number of collisions (*figure 5*) that occurred during the simulation (EEMD) is very high without prioritization, while prioritization allows no collisions (EEMD+).

The mean number of generated messages is approximately similar in EEMD, EEMD+ and ODAM (*figure 6*). The EEMD protocol generates more messages. This result can be explained by the fact that

EEMD generates three messages (two messages in a unicast mode and one message in a broadcast mode) to reach two hops, while it takes only two messages to ODAM (two broadcast messages) for the same number of hops. In case of EEMD without prioritization mechanism, collisions mean message loss which causes retransmissions.

Figure 7 shows mean number of redundant messages. A message is redundant when it is received more than once. ODAM gives the greatest values because all vehicles between a sender and a relay node receive the same message at least twice. This is due to the fact that the broadcast is performed each hop. In our protocols, few redundant messages are generated. They are due to the acknowledgment reception which is functional.

Small delays are reached in the simulations of the three protocols. The dissemination delay is the interval of time between the first generated message and the first message received by the last informed vehicle in the network. It is shown in *figure 8* that EEMD+ gives the best delays. This is due to the prioritization mechanism which eliminated collisions. In addition, in time-based protocols relay nodes have to wait a period of time before rebroadcasting which we consider as a waste of time according to the emergency of the application.

Generally, if a fragmentation occurs, the delay depends on the fragmentation duration.

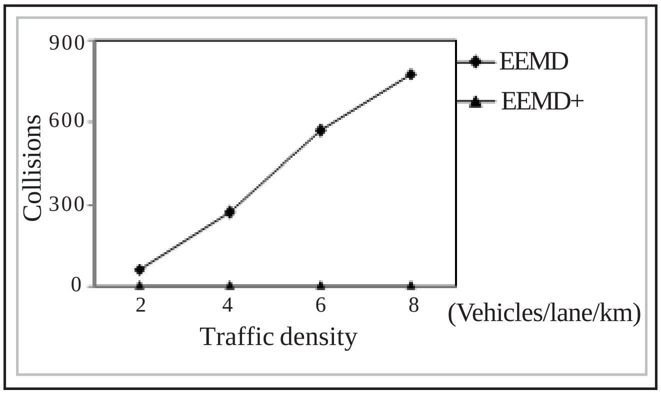

Figure 5. Collisions

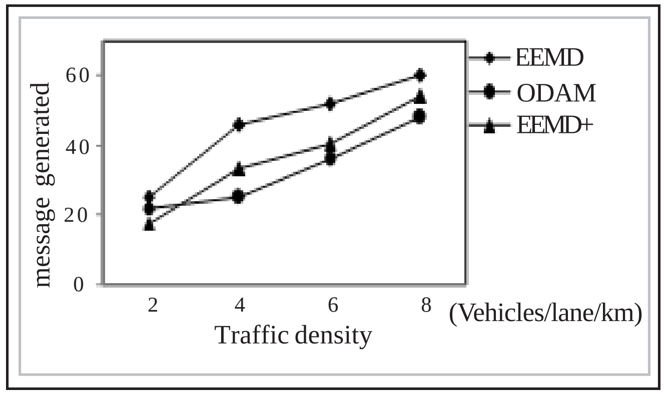

Figure 6. Generated messages

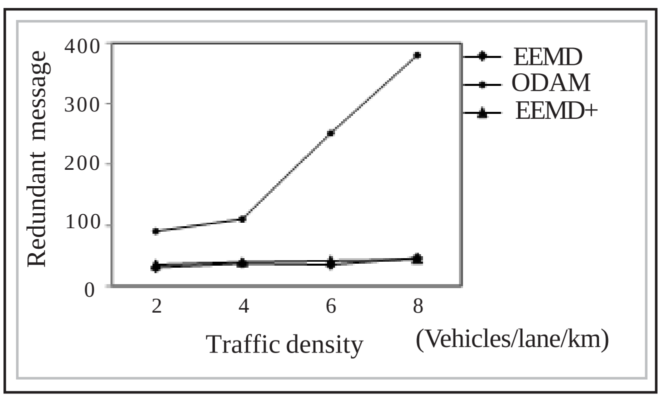

Figure 7. Redundant message

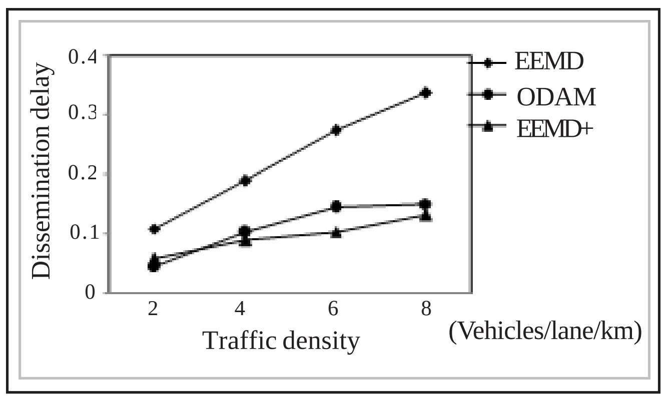

Figure 8. Dissemination delay

5. Conclusion

In this paper we showed that the use of the unicast mode in an emergency dissemination can give good performances in term of delay and efficiency. In the proposed strategy two processes get in progress at the same time. The first makes progress the dissemination process toward the rest of the vehicles while the second treats the broadcasting at each two hops. The unicat mode is used as a means of improving the broadcast mode, so that the broadcasted message can reach two hops simultaneously without redundancy. The EDCA prioritization mechanism used at the MAC layer permits to EEMD protocol to overcome collisions.

We can say firstly, that the unicast mode can be suitable for the dissemination service. Secondly, discarding the use of beacons for the reason that they cause collisions is not a good choice because on one hand most of the existing protocols especially routing protocols are topology-based, on the other hand beacon messages provide crucial information about the topology which can be used in several applications.

Our future work consists on proposing solutions at the MAC layer of the IEEE 802.11p protocol to enhance the existing dissemination protocols performances.

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