An Adaptative Broadcast Scheme for VANET Applications in a High Density Context

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***Abstract*—The efficient broadcast of messages in Vehicular Ad-hoc Network (VANET) still faces many challenges in current research. In this paper, we are interested in multi-hop broadcast communication for neighborhood discovery applications which increase driver visibility. These applications need to send information with a high rate causing congestion in the network. To avoid this congestion, we propose a new broadcasting scheme consisting in favoring the information of the closest vehicles in a high vehicular density context. Therefore, we introduce the concept of message energy, which generalizes the typical time-to-live value. Our proposal is evaluated and compared with several existing broadcasting schemas using a network simulator. The results show an improvement in neighbor discovery in a congestion context.**

***Keywords*-vanet; broadcasting scheme; scalability; auto-adaptive; simulation**

I. INTRODUCTION

Car-to-car communication systems are come very promising when it to enhancing security and safety during a trip. There are plenty of types of services/applications that can be built on top of a wireless device (from safety to entertainment applications). In this paper, we are focusing on broadcast-based applications. For instance, an application can send the geographical position of its vehicle to the neighborhood (Figure 1). For such applications, a routing functionality is not required.

We are interested in multi-hop broadcast communication for neighborhood discovery applications which increase driver visibility. When the vehicular density is high, we propose an auto-adaptive algorithm to compute the initial Time-To-Live (TTL) and interval of message sending depending on the local vehicular density.

This paper is structured as follows. First, we describe the later development in broadcast schemes. Then, we introduce our energy-based protocol. Finally, we compare our proposal with those already existing.

II. RELATED WORK

Many projects study applications for Vehicular Ad-hoc NETwork (VANET) [1]. Several applications need a broadcasting efficiency protocol [2]. Our application is based on this kind of protocol: the information on a vehicle (such as position, speed, type) is broadcast at regular intervals to their neighborhood in a geographical zone.

Flooding is the classical broadcast mechanism: each node in the network retransmits the received messages. This is a simple and easy method with a high delivery rate. However, it may lead to a very serious problem, such as the increasing of the bandwidth consumption and that may lead to high collision rates.

Many mechanisms have been proposed to limit the channel congestion. The main mechanism consists in reducing the number of relays [3]. Another proposal to limit channel congestion is power adjustment. The study of [4] estimates the local vehicle density to adjust the power transmission.

The optimal selection of relays has been described in most works [3], [5], [6]. To reduce the number of relays, the most popular method is the contention method with implicit acknowledgments [7], [8]. On receiving a packet, there is a contention delay for each node before forwarding the packet. The node receiving the forwarded packet cancels its own forwarding. Defining the contention delay value is a hard problem. First, the contention delay might be bounded by a maximal value. Second, the contention delay is computed from a random value, distance from a node (position of the previous sender, source, or destination) or a mix of multiple values.

A recent work [9] proposes a hybrid method between random value and distance from the previous sender. Beyond

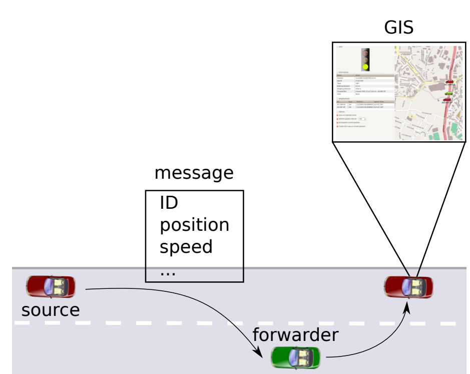

Figure 1. Our VANET application. A vehicle sends a message containing information. Its direct neighbors forward this message. Each vehicle writes in a table the information of all vehicles on the road. This information is displayed by a geographic information system (GIS) embeded in the vehicle.

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a distance threshold, contention delay is based on distance, but random value is used for the other nodes nearest to the sender. The aims of this work consist in reducing the delivery delay of a message.

A congestion control is proposed in [10]. An *abnormal vehicle* starts to transmit the *Emergency Warning Messages (EWM)* at a high rate and the EWM transmission rate is decreased over time until the minimum rate is reached.

In this paper, we propose a different approach. We would favor the information from the nearest nodes by introducing a new TTL-like value: message energy. Messages are initially sent at regular interval but with different initial energy levels. When a node forwards a message, energy decreases of at constant value. If the energy is inferior to a value proportional to the local node density, the message is dropped. Therefore, the average time between information update depends on both the distance from the source and the local density. A classic TTL does not have this property.

III. Proposed broadcast scheme

Our application consists in broadcasting the information about a vehicle. This information is the payload of a message whose header is described in Figure 2. *Information type* depends on vehicular information and defines the payload size, *hop* is the number of forwards for this message. *Sequence number* is a unique value. *Lifetime* is the information life time. *Node ID* is the vehicular ID. Longitude, latitude, elevation is the last forwarded node position.

Information type (16)	Hop (8)	Energy (8)
Sequence number (32)		
Lifetime (32)		
Node ID (128)		
Forwarder longitude (32)		
Forwarder latitude (32)		
Forwarder elevation (32)		
Vehicular information (n) ...		

Figure 2. Message header format

For our application, all the vehicles broadcast five kinds of information: type (car, truck, motorbike, bike, etc.), geographical position, speed, course and geolocation time. *Geolocation time* is the time given by the geolocation system. The format of this data is described in Figure 3

We note two occurences of the node position: one in the header, another one in the vehicle information. In message header, the geographical position is that of forwarder (relay vehicle) and is necessary for the distance-based protocols. Then, this position is updated at each hop. The position in

Vehicle type (16)	Reserved (16)
Source longitude (32)	
Source latitude (32)	
Source elevation (32)	
Speed (32)	
Course (32)	
Geolocation time (32)	

Figure 3. Vehicular information format

vehicular information is the position of the vehicle which has initially sent the message. This position is not revised during the broadcast.

A. Distance-based forwarding

Our proposed scheme is a distance-based forwarding. On message reception, a vehicle starts a timer T inversely proportional to the previous sender:

$$T = t_{max} * (1 - \frac{d}{R})$$

with t_{max} the maximum contention time, d the distance from previous sender, R the radio range.

The main issue with the distance-based approach is the duplication of forwarding. Indeed, the nodes close to the optimal position forward the message together in a short time. Thus, some duplications can occur, especially when the density of vehicles is high.

B. Energy message

We add the energy field in the message instead of the TTL value. On message reception, the energy value decreases by node weight:

$$E_{n+1} = E_n - W$$

with E_n the energy at n-th hops and W the node weight. This is already used with the classic TTL.

On message reception, a forwarding condition is added according to the energy value. The energy should be greater than a value according to local density. The higher the density, the higher the energy should be in order to forward the message. The following equation shows this condition forwarding:

$$E_n > \alpha N_R$$

with N_R the number of vehicles in a R range, α the penalty factor. We can retrieve the TTL mechanism in a classic protocol when $\alpha = 0$.

The initial energy value might be set according to the message range required. The higher the initial value, the further the message goes away. In addition, the message range depends on the local density: the energy of a message should be high enough to cross the high density zone.

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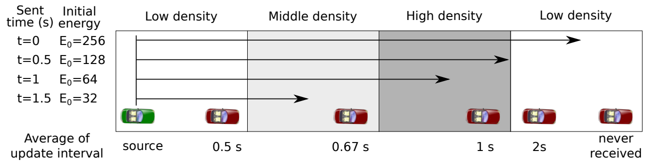

Figure 4. The messages are sent at different times. Depending to road density and distance from source, the average of update interval is different for the vehicles.

We would broadcast vehicular information at regular intervals to update this information for the neighborhood. But we favor the nearest vehicular information. Then, in the case of high density, the nearest vehicles can receive information more often. Therefore, we propose to set different initial energies depending on when the message is sent (Figure 4). For instance, with the update interval set at 500 ms, at $t = 0$ the initial energy E_0 is set at 256, at $t = 0.5$, $E_0 = 128$, $t = 1.0, E_0 = 64$, and $t = 1.5, E_0 = 32$. At $t = 2.0$, the initial energy goes back the maximal value $E_0 = 256$. Then, we define two values: E_{0max} and E_{0min}. Here, $E_{0max} = 256$ and $E_{0min} = 32$.

C. Local density evaluation

We define local density as the number of vehicles in a range R. Therefore, a vehicle computes the distance d from the initial sender with the geographical position incorporated into the message. Then, the density is the number of vehicles with $d < R$.

We notice that estimating the local density as the number of one-hop messages received by a vehicle is not a good idea. Indeed, the density is not proportional to the number of received messages due to the interferences proportional with the number of nodes. Therefore, the local density is computed from any received message without taking into account the number of hops from the source.

IV. Performance evaluation

In this section, we evaluate the performances of our proposed broadcast scheme. We compare our protocol to several other protocols. In the following, we introduce the used metrics, a detailed description of the other protocols, the simulation details, and, finally, the results.

A. Used metrics

The main metric is the number of discovered vehicles N_d. This value must be compared to the total number of vehicles N in the network. Ideally $N_d = N - 1$, the sender not being taken into account. The delivery delay is the time between the message sending and its receipt. The maximum contention time affects this delay. In high density, the message queuing in the MAC layer affects it also. Finally, the time between information update is the metric to evaluate the wrong effect with our proposed protocol. Indeed, some messages with lower energy do not reach all the vehicles, increasing the time between information update.

B. Other evaluated protocols

We compare our proposal with four other protocols:

(1) Flooding is the simplest protocol: all the new messages received are forwarded.
(2) A simple distance based protocol (SDP), consists of a contention delay proportional to the distance from the previous sender as described in [9].
(3) A third class of protocol is random-based [11]. The contention time is a random value between zero and t_{max}: $T = random(0, t_{max})$.
(4) Finally, the protocol introduced in [9] is also evaluated. We call it *threshold*. This is a hybrid method between random-based and distance-based protocols to reduce the delivery delay.

$$T_{upper} = \begin{cases} t_{max} * (1 - \frac{d}{R}) & \text{where } d > d_{th} \\ t_{max} & \text{where } d \leq d_{th} \end{cases}$$

$$T_{lower} = \begin{cases} 0 & \text{where } d > d_{th} \\ t_{max} * (1 - \frac{d_{th}}{R}) & \text{where } d \leq d_{th} \end{cases}$$

$$T = random(T_{lower}, T_{upper})$$

Where d_{th} is the *distance threshold* constant.

C. Simulations details

We use the OPNET Modeler [12] network simulator to evaluate the protocols. The OPNET modeler supports some mobility models: random way-point, trajectory and satellite. Trajectories are defined as files containing node positions at multiple times. No vehicular mobility model exists for the OPNET Modeler. But we have developed a framework [13] to use SUMO [14] with the OPNET Modeler. SUMO generates vehicular positions in a trace file and our framework converts this trace to trajectory files and a project file for the OPNET Modeler. Thus, we can use a realistic mobility scenario to evaluate the protocols.

Protocols are implemented in the routing layer above the Medium Access Control (MAC) layer IEEE 802.11b. But back-off contention delay can disrupt the contention delay in the proposed protocols. Indeed, in high density, messages are queued to wait for the medium access. To bypass this problem, we set queuing size to one message. If the queuing is full, the message is dropped, but a neighboring vehicle will send the same message after its contention waiting time.

The scenario consists of a simple one-way road with three lanes and a length of 15 km. The vehicles are initially uniformly distributed on 10 km. We increase the density by increasing the number of vehicles from 50 to 450. The simulation duration is 10 s.

MAC layer bitrate is 11 Mbit/s, with message length at 544 bits. The real radio range is about 550 m. Thus, we define R at 550 m as a parameter for our protocol.

Simulation length	10 s
Length of vehicle convoy	10 km
Number of vehicles	50 to 450
MAC layer	IEEE 802.11b
Radio range (R)	550 m
Bitrate	11 Mbit/s
Message length	544 bits
Message sending interval	500 ms
Maximal contention time t_{max}	100 ms
Distance threshold d_{th}	170 m
Maximum initial energy E_{0max}	256
Minimum initial energy E_{0min}	32

Table I
SIMULATION DEFAULTS PARAMETERS

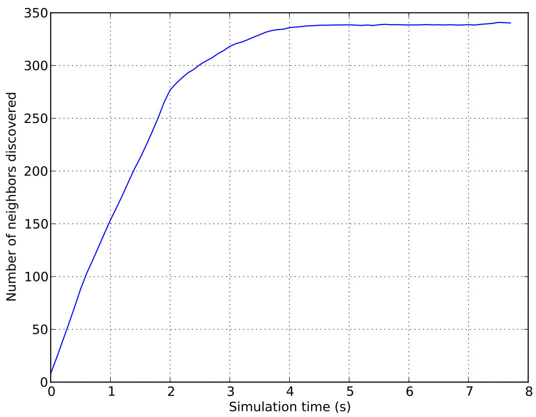

Figure 5. Number of discovered neighbor over time. The convergence time is about 5 seconds.

The default t_{max} is 100 ms. The distance threshold d_{th} for threshold protocol is 170 m. For our proposed protocol, the initial energy is fixed as follows: $E_{0max} = 256$ and $E_{0min} = 32$. Energy is divided by two for each new hello message sent until $E_n < E_{0min}$.

All parameters and there default values are summarized in Table I.

D. Simuation results

1) Convergence time: To set simulation time for the next evaluations, we want to know how long it takes the number of discovered neighbors to reach a maximum, i.e., the *convergence time*. This convergence time is the consequence of our application which has a multi-hop aspect. No free canal, error of transmit, or null energy in the message involves message dropping. Thus, the vehicle must wait for the next message to add the neighbor in his table.

Figure 5 shows a convergence time of about 5 seconds (ten times the message sending interval) with 350 vehicles reachable. Between zero and 2 seconds, the number of discovered neighbors increases linearly to reach about 275 vehicles.

We conclude that a simulation time of 10 s is adequate.

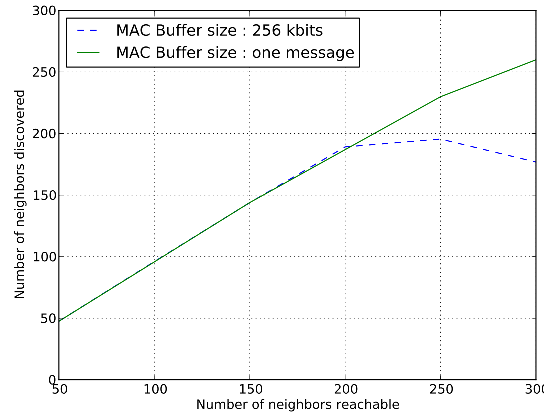

Figure 6. Neighbor discovery depending to the number of reachable vehicles. Limiting MAC buffer size allows us to improve network capacity.

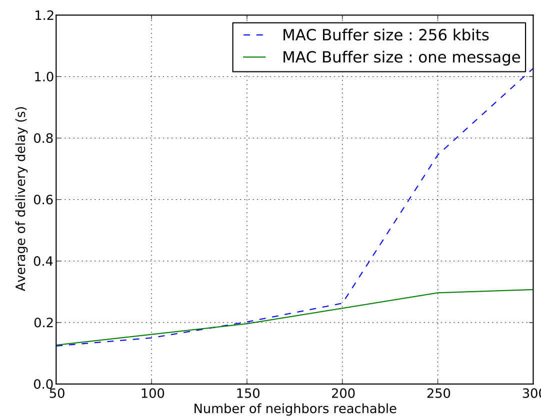

Figure 7. Average of message delivery delay depending to the number of reachable vehicles. With a small buffer size, messages do not waiting in MAC queue.

2) Ajust MAC buffer size: To avoid a wrong effect of contention in IEEE 802.11b MAC layer, we evaluated a simple distance-based protocol with two buffer sizes: OPNET default (256 kbits) and size of one message (544 bits). Thus, either the canal is free and the message is transmitted, or the canal is busy and the message is dropped.

We can see in Figure 6, with a buffer size at 256 kbit, the maximum number of neighbors discovered is above 200. But a buffer size corresponding to one message allows us to discover more than 250 neighbors when the total number of reachable vehicles is 300.

In addition, with a buffer size at 256 kbit, the delivery delay explodes from 200 neighbors (Figure 7).

Limiting the buffer size implies that the message does not wait in the MAC layer queue and the delay remains constant when the network traffic increases. The results in

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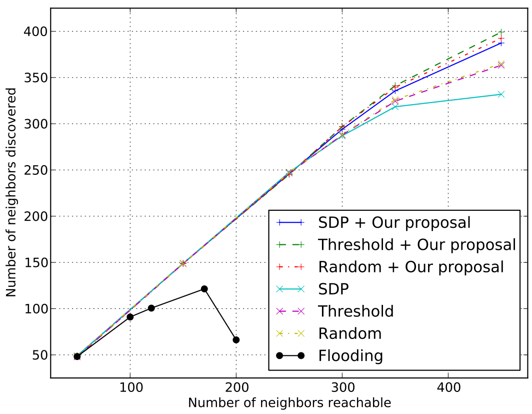

Figure 8. Neighbor discovery depending to the number of reachable vehicles.

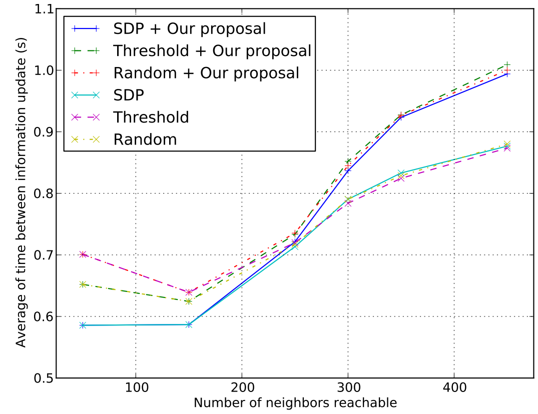

Figure 9. Average of information update interval depending to the number of reachable vehicles.

Figure 9 confirm this hypothesis. For the next simulation results, the buffer size limit is one message, except for the flooding protocol.

3) Capacity evaluation: We would evaluate protocols introduced in the above by varying the total number of reachable vehicles on the road. Thus, we evaluate protocol achievement in a high vehicular density context with and without our broadcast scheme.

As expected, the maximum number of discovered neighbors with flooding protocol is low, about 120 and SDP protocol improves considerably the number of discovered neighbors (Figure 8). The random-based protocols (Random and Threshold) allow us to limit the duplication of message forwarding in high density context (more than 250 vehicles). Thereby, the number of discovered neighbors is greater than with SDP protocol.

Our proposal allow an increase of the number of discoreved neighbors for three of the evaluated protocols. Indeed, messages with low initial energy do not reach all nodes and the number of forwarded messages is lower and the network capacity is not reached with 450 vehicles. We can see that the maximum number of discovered neighbors is reached by the *threshold* protocol. In a trade-off, the update interval of vehicle information is less for vehicles further away (Figure 9).

In high density context, many messages are lost. That is why the interval update information without our proposal grows with the number of vehicles. Our proposal prevents this message loss by reducing the number of messages sent by the source.

Although message delivery delay is not the main preoccupation for our VANET application, Figure 10 show this result. Random-based schemes allow to reduce the delay as described in [9]. The *threshold* protocol with our proposal is the best in terms of delay. Thus, our improvement in the

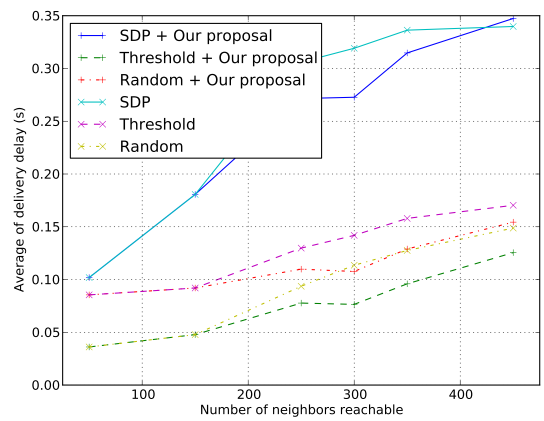

Figure 10. Average of message delivery delay depending to the number of reachable vehicles.

number of discovered neighbors has no impact on message delivery delay.

4) Optimal penalty evaluation: Previouly, the penalty has been set at the arbitrary value 1. An optimal penality value could be determinate with a theorical model but this is part of our future works.

The penalty value impacts on the neighborhood discovery. Indeed, the higher the penalty, the lower the distance traveled by the message with the same initial energy. But, if penalty is too low, our proposal scheme does not improve performance.

Figure 11 confirms this hypothesis. The number of vehicles is set at 350. Between 1 and 3, the number of discovered values is maximal.

To refine this value, we observe the information update interval in Figure 12. With a penalty value between 1 and 3, the best information update interval is with 1 and 1.5 penalty values. Then, a value equal to 1 for the penalty is correct.

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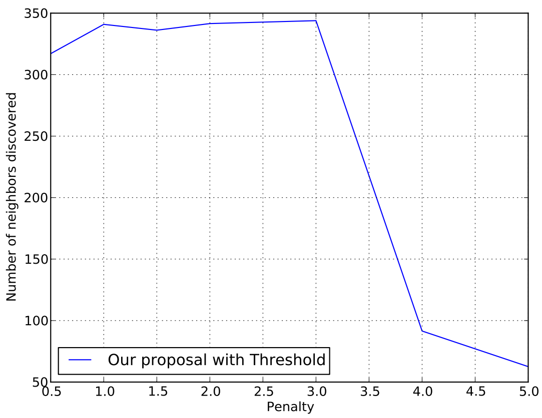

Figure 11. Neighbor discovery depending to the penalty value.

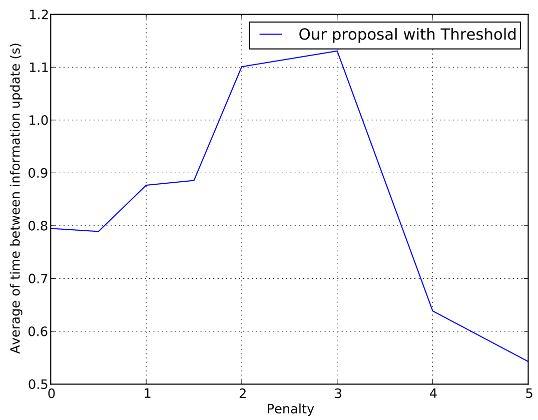

Figure 12. Average of information update interval depending to the penalty value.

V. Conclusion And Future Works

We have proposed a new broadcast scheme by adding the concept of message energy. This energy value is a generalization of the typical time-to-live value allowing us to consider both distance from the source and the local density. Therefore, this scheme favors the information of closest vehicles, limits the number of forwarded messages and the network congestion in a vehicular high density context. These properties are adapted to VANET applications which broadcast information (geographical position, speed, course, type, etc.) to vehicles on the road. We have evaluated our proposal with some other existing schemes and we improve the *threshold* scheme proposed recently in a high vehicle density context. Our future work will concern the development of a model to compute the *penalty* optimal value and initial energy values and improve neighbor discovery. We want to go into more concerning detail message queuing problems in the MAC layer.

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