# Impact of Concurrent Communications in Geographical Broadcasting Protocols for Vehicular Ad hoc Networks

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***Abstract*—Bringing to the market intelligent vehicles is one of the current challenges faced by car manufacturers. These vehicles must be able to communicate in order to cooperate and be more effective. The issue of inter-vehicle communications is an active research topic. This paper proposes a reliable geographical broadcasting protocol which has a twofold goal: limiting the risk of interference and reducing the dissemination time. To achieve theses goals, two mechanisms are proposed. The first one divides the road (more precisely, each vehicle's coverage area) into several segments depending on the local density. Thereafter, the priority to relay a message is given to nodes that are in the farthest segment from the source node. The second mechanism allows to reduce the waiting time thanks to a periodic update process. This paper also analysis the performance of geographical broadcasting protocols in case of multiple simultaneous communications. The goal is to observe how these protocols behave when the radio channel becomes overloaded. The comparison study (in terms of packet loss and dissemination time) shows that the proposed protocol outperforms two other VANETs' broadcasting protocols.**



***Index Terms*—Vehicular ad hoc networks, IEEE 802.11p, Geographical broadcasting protocol, Segmentation, Waiting time adaptation.**


## I. Introduction

During the recent years, intelligent transport systems (ITS) have contributed to improve users' mobility. These systems are particularly interested in the safety and comfort of users. Some of the ITS specifically address issues related to intelligent vehicles: how to make them more autonomous and how to ensure the quality of communication between vehicles. This paper focuses on inter-vehicle communication issues.

Vehicles communicate using wireless technologies, including the IEEE 802.11p standard. The interconnection of vehicles forms a Vehicular ad hoc network (VANET). This network has three main objectives: improving road safety (eg. sending emergency messages), streamlining road traffic (preventing traffic jam) and providing more comfort (Internet access, online games, tourist attraction). These tasks are carried out using vehicle to road infrastructure communication (V2I), vehicle to vehicle communication (V2V), or vehicle to any other device communication (V2X). In V2V, each vehicle acts as a client and a relay (router) node. Indeed, to spread a message over a long distance, vehicles should collaborate and apply a relaying strategy between neighbors. The choice of the best relays in terms of number, quality, and reliability is not a trivial task. In high-density networks, too many relay nodes would increase the risk of interference, leading to the saturation of the bandwidth and a significant increase of the latency. Conversely, if there are not enough relay nodes in low-density networks the message may not be widely disseminated. In the literature, several works have proposed broadcast protocols to deal with this problem.

This paper introduces a novel geographic approach of broadcasting messages in VANETs. This method divides nodes' coverage area into segments and gives priority to farthest nodes. This novel segmentation method reacts to network density changes. Furthermore, it deals with the empty segment problem. The proposed approach also allows nodes to dynamically adjust their waiting time in order to shorten the dissemination time. This paper also aims to analyse the behaviour of geographic broadcasting protocols in VANETs when taking into account simultaneous communication (which may overload the radio channel).

The remaining of the paper is organized as follows. Section II presents the main families of broadcasting protocols. The proposed protocol and its main features are detailed in Section III . Sections IV and V give experimentation parameters and a comparative study of three broadcasting protocols. Section VI concludes this paper and points-out some future work.

## II. Related Work

Broadcasting consists in sending a message from one node to all other nodes within a network. In VANETs, wide dissemination of messages can only be ensured if some nodes relay the packets they receive. Moreover, the fact that nodes share the radio channel requires designing broadcasting strategies that minimize the risk of interference. This can be achieved by reducing the number of relays in high-density networks.

This reduction should not lead to the interruption of the message propagation. Finding a good broadcasting strategy is complex in VANETs (in wireless ad hoc networks in general) because the decision to relay or not each message is taken in a decentralized way. This means none of the nodes have information on the overall network topology. Each decision is taken according to local information. Broadcasting protocols can be classified into deterministic and stochastic categories.

### A. Deterministic methods

A broadcasting method is deterministic if its process is predictable. This category includes simple flooding and neighbor knowledge-based methods.

*1) Simple flooding:* it is the simplest broadcasting method. Every packet is relayed exactly once by each node. Any redundant copy of the packet received later is ignored. One drawback of this method is that it does not take into account the network density. In high-density networks, this method would generate many redundant copies of broadcasted packets, leading to the overuse of the radio resources.

*2) Neighbor knowledge-based methods:* they compare neighbor lists before relaying packets. Nodes exchange Hello packets in order to discover the local network topology and to build up their neighbor lists. The Flooding with Self Pruning [1] uses a 1-hop neighbor list. This list is inserted into the broadcast packets. This allows each receiver to compare its own list to the one included in this packet. If the lists are identical, the packet is dropped. Otherwise, the packet is relayed. Other methods such as Distributed Vehicular Broadcast (DV-CAST) [2] and Least Common Neighbor (LCN) [3] also rely on 1-hop neighbor lists.

For static or low mobility networks, neighbor knowledge-based methods can achieve good performance. But in high mobility networks like VANETs, information about the neighbors become quickly inaccurate. Thus, this family of methods is hardly applicable for vehicular networks.

### B. Stochastic methods

The stochastic methods statistically assess the gain that could be obtained if the packets are relayed by a given node. They include probabilistic scheme, counter-based and location-based methods.

*1) Probabilistic methods:* in these schemes, the receiver calculates a dissemination probability based on a defined parameter. For instance, in [4] the authors associate the forwarding probability of a node to its distance from the source so that the farthest node will have a high chance to rebroadcast the packet. In [5], [6], [7] the rebroadcasting probability depends on the node's local density, node's speed, and redundancy ratio respectively. In [8] the authors propose a protocol called E-ProbT that combines the number of common neighbors and the distance between the transmitter and the receiver to compute the probability of forwarding.

Smart-flooding [9] aims to adapt the broadcasting probability to the local density. In addition to the probability, this protocol introduces three other parameters: the number of retransmissions for each packet, the delay between successive retransmissions and the TTL (time to live). To achieve good tuning of these parameters for various density levels, the authors have used a genetic algorithm.

*2) Counter-based methods:* they rely on a simple principle: the more a node receives copies of the same packet, the less likely it is useful to relay this packet. Upon reception of the first copy, the node initializes a counter $C$ to 1 and sets a timeout RAD. During the waiting period, $C$ is incremented upon reception of a new copy of the packet. When the RAD expires, $C$ is compared to a threshold value $C_t$. If $C < C_t$, the packet is broadcasted. Otherwise, it is dropped. Like probabilistic methods, one challenge is to find an appropriate value of $C_t$. Yassein et al. [10] proposed the Smart Counter Based Broadcast Algorithm that adapts $C_t$ according to the network density. Thanks to Hello packets, the nodes build neighbor lists. The size of these lists allows to dynamically adjust $C_t$. Karthikeyan et al. introduced in [11] a method named Density Based Flooding Algorithm. This method defines two categories of nodes according to their number of neighbors, with respect to a given threshold $\tau$. Each node decides to relay each packet depending on its own category and the one of this packets last hop.

*3) Geographical methods:* they try to increase the additional coverage area that will result if the packet is forwarded. These methods do not consider whether nodes exist within that additional area or not. AckPBSM [12] and POCA [13] use this approach and set lower RAD to nodes that are far from the source node. To evaluate the extra coverage area, the node can use the distance between itself and each node that has previously relayed the message (distance-based scheme) or the geographical coordinates (location-based scheme). In both distance-based and location-based schemes, a RAD timeout is set and the message is relayed if the additional coverage area is higher than a given threshold.

To resolve the broadcast storm problem [14] and have a high reliability, authors in [15], [16], [17] use the segment-based technique. They divide the road into multiple segments and vehicles within the farthest non-empty segment are in charge of relaying the packets. Its major disadvantage is the creation of empty segments since they are density-unaware methods.

## III. A HYBRID SENDER AND RECEIVER ORIENTED BROADCASTING PROTOCOL

A broadcasting protocol is sender-oriented if the node that sends the packet chooses the relay nodes. For example, it can include the list of relay nodes in the packet header. In a receiver-oriented approach, each receiver node autonomously decides whether to relay the packet or not. It is worth noting that when packet propagation conditions are good, sender-oriented protocols can give good results. However, if many packets are lost, it is possible that the relay nodes chosen by the source do not receive the packet. Such a situation could lead to the disruption of the broadcast. Therefore, when the risk of interference is high, the receiver-oriented approaches seem more interesting.

This paper introduces a new novel broadcasting protocol that combines the sender-oriented and receiver-oriented methods. This protocol is named Segment-Delay Based Broadcasting Protocol (SDBP). SDBP is sender-oriented in the sense that the source helps the nodes with some information encapsulated in the packet header. On the other hand, it is a receiver-oriented protocol because each node acts autonomously after receiving the packet.

In order to ensure a wide dissemination of packets, efficient broadcasting protocols must take account of the network density. To this end, SDBP uses a segmentation method that relies on local density level and avoids creating empty segments. Furthermore, SDBP uses a dynamic adaptation of the waiting time for each node. SDBP is a geographical broadcasting protocol which consists of three main phases:

1) the neighbor discovery phase
2) the sending phase
3) the forwarding phase

These key steps are illustrated on Figure 1. They are detailed in the Sections III-A to III-C.

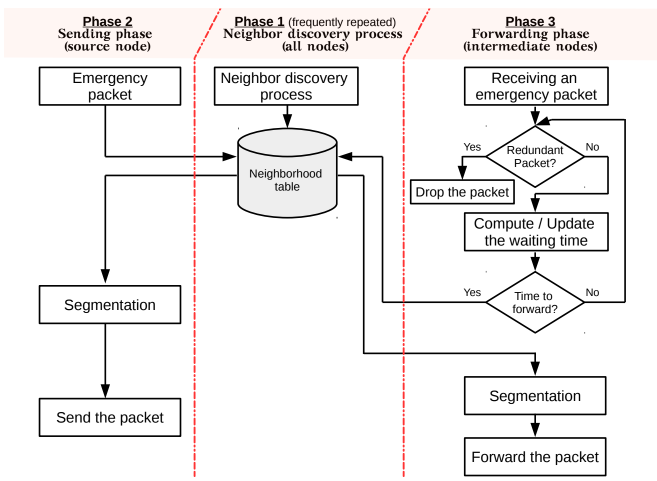


Fig. 1. Main steps of SDBP

## A. Neighbor discovery phase

The neighbor discovery process is carried out by all nodes. This process is regularly repeated because the VANETs are highly mobile networks, resulting in frequent topology changes. SDBP uses periodic Hello packets to discover neighbors. These packets contain the following information: $\langle VehicleID, PacketID, X\text{-}coordinate, Y\text{-}coordinate \rangle$ (see Figure 2). When a node receives a Hello packet, it adds the packet's source information into its neighborhood table. Each record in the table has an expiration time (to deal with inactive neighbors caused by a link failure, collision, etc.). This expiration time is three times the Hello packets frequency.

The neighborhood table will be used to estimate density and segment the sender's coverage area. The segmentation is performed before each sending or forwarding phase.

| | | | |
|---|---|---|---|
| VehicleID | PacketID | X-coordinate | Y-coordinate |

Fig. 2. SDBP Hello Packet Header

## B. Sending phase

This phase corresponds to the initial sending of a packet. The source node efficiently chooses its neighbors that will relay the packet. Since SDBP seeks to avoid the drawbacks of sender-oriented protocols, it does not precisely identify the relays. Rather, it segments the network in such a way as to favor the farthest nodes. In literature, segmentation is generally done in a regular way. That means the source node's coverage area is divided into several segments of the same width. One of the disadvantages of this method is that it does not deal with the density (the number of nodes within the segments may vary). Moreover, if the nodes are not uniformly distributed, the farthest segments may be empty. This leads to the empty segment problem [4], [15], [17]. SDBP introduces a novel approach that tackles this problem. In SDBP, the number of segment relies on the local density of each node (number of neighbors) and it does not merely depend on node's transmission range. In real world context, the transmission range is usually unknown since it is inconstant and varies swiftly depending on the signal propagation environment.

SDBP divides the source node's coverage area into $K$ segments, depending on the number of neighbors, say $N$ (see Equation 1). $N$ is estimated thanks to the neighborhood table (see Figure 1). All the segments contain the same number of nodes ($M_i$), except the farthest segment if $N$ is not a multiple of $K$ (see Equation 2).

$$K = \lfloor \sqrt{N} \rceil \qquad (1)$$

$$M_i = \begin{cases} \dfrac{N}{K} + (N \bmod K) & \text{if } i\text{=1 (the farthest segment)} \\ \\ \dfrac{N}{K} & \forall i \in \{2, 3, ..K\} \end{cases} \qquad (2)$$

The boundaries of each segment are calculated using Equation 3. Figure 3 illustrates an example of the segmentation of the coverage area of vehicle S. Let us recall that the segmentation aims to reduce the interference and the dissemination time of packets. Therefore, priority of relaying messages should be given to nodes that are in the farthest segment. Consequently, each node must be aware of the segment it belongs to. For this purpose, the segments' boundaries are included in the packet header (see Figure 4).

$$
\begin{cases}
n_i = (N+1) - \sum_{j=1}^{i} M_j \\
Dmin_i = n_i^{th}\ neighbor's\ position \\
Dmax_i = \begin{cases} Farthest\ neighbor's\ position & \text{if } i = 1 \\ Dmin_{i-1} & \text{if } i \in \{2,3,..K\} \end{cases}
\end{cases}
\tag{3}
$$

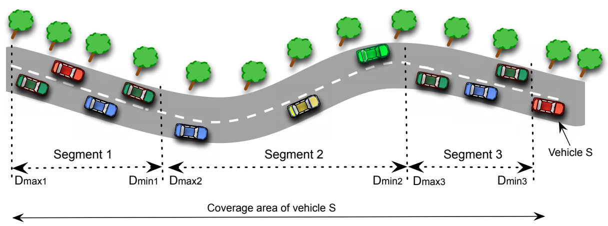


Fig. 3. Example of the segmentation of a node's coverage area

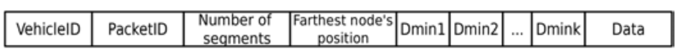


Fig. 4. SDBP's data packet header

### C. Forwarding phase

The forwarding phase starts when an intermediate node (say $r$) receives a packet. If it is the first copy of the packet, the node initialises a counter to compute the number of redundant copies. Then, it determines to which segment it belongs to and calculates its waiting time $WT$ according to Equation 4.

$$WT_r = i \times SlotTime \times \frac{d(Source, FarthestNode)}{d(r, Source)} \tag{4}$$

where $i \in \{1, 2, \ldots, K\}$ is the segment's number, $d$ represents the distance between two nodes and $SlotTime$ is an approximate time for a packet to be thoroughly received by the other neighbors. In this work, we use the $SlotTime$ value proposed in [7].

Afterwards, a timer is triggered which is the minimum between waiting time and $SlotTime$. At the timer's expiration, four cases may be distinguished:

- If the node has received a redundant copy, the packet is dropped.
- If no copy has been received by the node and its waiting time is expired ($WT = 0$), the node forwards the packet.
- If the waiting time of the node has not expired yet and it is still greater than $SlotTime$, the node updates its waiting time using the Equation 5.
- Else, the minimum value between $WT$ and $SlotTime$ is selected again and the process restarts.

$$WT'_r = \frac{WT_r}{2} \tag{5}$$

TABLE I
SIMULATION PARAMETERS

| | |
|---|---|
| Network Simulator | NS-2.35 |
| MAC protocol | IEEE 802.11p |
| Propagation model | m-Nakagami |
| Highway Length | 8 km |
| Number of lanes | 2 |
| Number of nodes | 267 |
| Percentage of data packet sources | 1%, 5%, 10%, 15%, 20%, 25% |
| SlotTime | 4ms |
| Number of runs for each simulation | 10 |

TABLE II
NAKAGAMI PARAMETERS

| gamma0_ | gamma1_ | gamma2_ | d0_gamma_ | d1_gamma_ |
|---|---|---|---|---|
| 1.9 | 3.8 | 7.6 | 150 | 300 |
| m0_ | m1_ | m2_ | d0_m_ | d1_m_ |
| 1.5 | 0.5 | 0.25 | 80 | 200 |

The waiting time adjustment helps hastening the dissemination process mostly in a network where there are many obstructions that prevent the good reception of packets. In actuality, when a node broadcasts a packet, it does not know which nodes will receive the packet and which ones will lose it. For instance, in a network where the message is lost by all nodes falling farther from the source, the nearest neighbors of the source must wait a lengthy time before broadcasting the message. This situation would result in an enormous increase of the end to end delay.

## IV. SIMULATION PARAMETERS AND PERFORMANCE CRITERIA

### A. Simulation parameters

This paper aims to study the performance of geographical broadcasting protocols, especially when there are several competing communications. This study is carried out using the Network Simulator 2 (NS2, version 2.35) [18]. We simulated a linear topology of 267 vehicles lined up over 8km. Vehicles' speeds vary from 40 $km/h$ to 50 $km/h$ (in the same direction). This scenario simulates mobility in an urban area.

Concurrent communications are simulated by increasing the number of packet sources. We start with 1% of the nodes that simultaneously send a packet. Then we gradually increase this value up to 25% simultaneous data traffic. The goal is to observe the behavior of the broadcasting protocols when the radio channel becomes overloaded. The simulation parameters are summarized in Table I.

To assess the performance of the protocols, we used the Nakagami radio propagation model. We tuned it to get a non-deterministic behavior in order to be as realistic as possible. The parameters of this propagation model are summarized in Table II.

### B. Performance criteria

We compare two geographical broadcasting protocols: SDBP and FDP (Furthest Distance Protocol) [19]. FDP is a sender-oriented distance-based dissemination technique where the twelve farthest nodes from the source are selected as forwarders. In addition to these two protocols, we present the results of the Simple Flooding Protocol (SFP), the well-known technique where nodes broadcast each received packet only once (the first time) without any waiting time. SFP is taken as a reference since it is the simplest broadcasting protocol.

In this study, we focus on the propagation of the message within a Zone Of Relevance (ZOR). Since in this paper we consider the dissemination of an emergency message in a VANET, the ZOR is defined as $2000m$ road section behind the source node. Indeed, the vehicles which present the greatest risk are those which are located in the vicinity of the vehicle that detects an unexpected road hazard.

The comparison study is carried out with respect to three performance metrics.

1) Unreachability ratio: the percentage of nodes in the ZOR that have not received the packet;
2) Number of dropped packets: number of packets discarded at the physical layer due to the following motives [20]:
   - Transmission Busy (TXB): this scenario occurs when a node in a transmission state receives another packet. Because a node can not send and receive at the same time, the packet which was supposed to be received will be dropped.
   - Reception Busy (RXB): in this case, a node receives a second packet while it is busy by receiving another packet. This situation will cause a collision.
   - Searching valid preamble (SXB): in this situation, the node which is in an Idle state drops the packet because it is searching for a valid preamble.
   - Receiving a frame preamble (PXB): as the previous case, the node is in an Idle state but it can not receive correctly the current packet because it is busy by receiving a valid preamble of another packet.
3) Dissemination time: the required time in order that all nodes within the ZOR receive the packet;

## V. Analysis of the impact of concurrent communications

The results presented in this section are the average values (of the total number of runs indicated in Table I) and the confidence interval (with a confidence level of 95%) for the performance metrics detailed in Section IV-B.

### *A. Packet loss*

When an emergency message is broadcasted in a VANET, one of the first challenges is to insure that the packet will be received by all vehicles in the vicinity of the source node. A good reception in this area would limit the risk of accident or a multi-vehicle collision. Figure 5 shows the rate of vehicles that did not receive the message within the ZOR. When there are 1% source nodes, the three protocols fully cover the ZOR. Subsequently, the performance of SFP degrades very quickly. This behavior is due to the fact that all nodes relay the packets they receive. Therefore, in case of multiple competing data traffics, the risk of interference increases. Regarding the geographic protocols, we note that SDBP's results are not sensitive to the number of competing data flows. On the other hand, FDP's unreachability ratio increases with the number of sources. Indeed, since FDP uses an approach where the selection of relay nodes is done by the sources, this protocol is sometimes penalized when no selected node receives the message because of collision or mobility. It is worth noting that SDBP does not provide a list of potential relay nodes. Any neighbor could relay the packet, depending on the segment it belongs to.

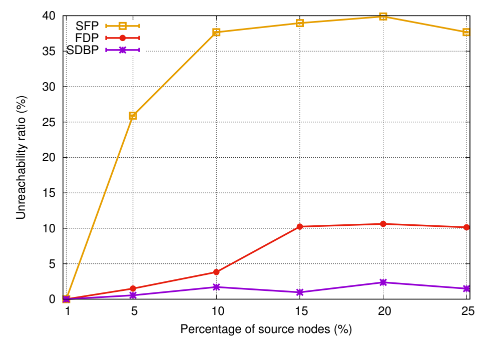

Fig. 5. Unreachability ratio

Packet losses within the ZOR can also be explained by their cause. Figure 6 shows that SDBP has a number of packet loss due to RXB slightly higher than FDP. This happens because SDBP reduces the waiting time in order to speed up the broadcast. The positive effects of this adaptation on the broadcasting time will be presented in Section V-B. The number of dropped packets due to RXB stabilizes. This shows that SDBP is able to adapt to the network load.

Usually, reducing the waiting time leads to overloading the network and to increasing the number of dropped packet. The most important thing to notice about the four histograms of Figure 6 is that the mechanism proposed by SDBP to update the wating time has a negligible effect on packet loss.

### *B. Dissemination time*

Concerning the dissemination time (Figure 7), SFP's results are not relevant. Indeed, these low values are calculated on a small number of nodes, because of the low packet delivery ratio of this protocol. In general, the only nodes that receive the packet are 1 or 2 hops from the source. SDBP obtains a dissemination time which is generally not very sensitive to the number of source nodes because it uses a dynamic waiting time adjustment mechanism (which is not the case for FDP).

## VI. Conclusion

This paper has introduced a new geographical broadcasting protocol for vehicular networks. This protocol, named SDBP, has two main mechanisms. The first mechanism segments the coverage area of each node depending on the local density level. It avoids the creation of empty segments. The second mechanism adjusts the waiting time in order to speed up the

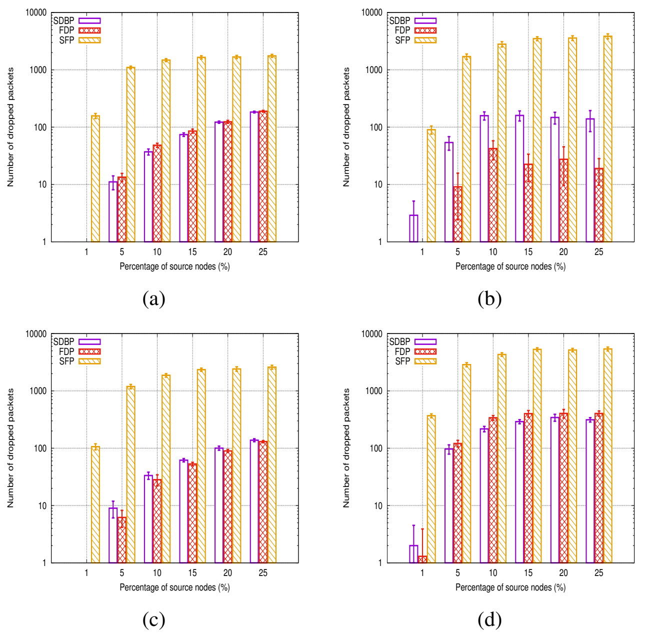


Fig. 6. Number of dropped packets due to (a) TXB, (b) RXB, (c) SXB and (d) PXB in urban environment

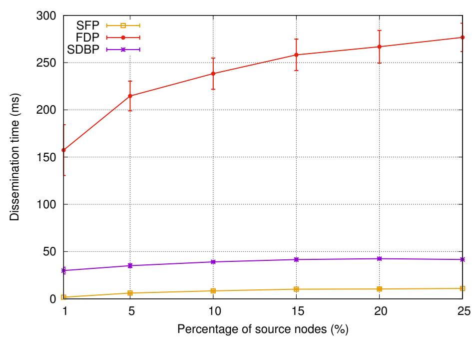


Fig. 7. Dissemination time

broadcasting process. The comparative study carried out shows that SDBP allows efficient packet delivery. It allows almost all vehicles within the zone of relevance to be reached in a very short time. The study also shows that method of reducing the waiting time introduced by SDBP has a negligible impact on the packet losses. As future work, we will investigate the benefits of the mechanisms proposed by SDBP on the number of relay nodes and packet redundancy. These two values will confirm the scalability of SDBP. It would also be interesting to adapt the waiting time with respect to the network density (not only to the segment the node belongs to).

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