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Priority Levels Based Multi-hop Broadcasting Method for Vehicular Ad hoc Networks

Wahabou Abdou · Benoît Darties · Nader Mbarek

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Abstract This paper deals with broadcasting problem in Vehicular Ad hoc Networks (VANETs). This communication mode is commonly used for sending safety messages and traffic information. However designing an efficient broadcasting protocol is hard to achieve since it has to take into account some parameters related to the network environment, for example the network density, in order to avoid causing radio interferences. In this paper, we propose a novel Autonomic Dissemination Method (ADM) which delivers messages in accordance with given priority and density levels. The proposed approach is based on two steps: an offline optimization process and an adaptation to the network characteristics. The first step uses a genetic algorithm to find solutions that fit the network context. The second one relies on the Autonomic Computing paradigm. ADM allows each vehicle to dynamically adapt its broadcasting strategy not only with respect to the network density, but also in accordance to the priority level of the message to send. The experimental results show that ADM effectively uses the radio resources even when there are globally many messages to send simultaneously. Moreover, ADM allows to increase the message delivery ratio and to reduce the latency and radio interferences.

Keywords VANET; Broadcast; Autonomic; Message priority level; Density evaluation; Quality of Service; Optimization

1 Introduction

A Vehicular Ad hoc Network (VANET) is a collection of vehicles communicating through wireless connections: each vehicle acts simultaneously as a node and as a wireless router, allowing multi-hop packet forwarding. Indeed, each node has a limited coverage area that contains the neighbours it can directly communicate with. This area can vary from one hundred meters to a few kilometers (depending on the

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wireless technology on-board, external radio interferences,...). Using vehicle-to-vehicle communications allows sending packets over wide distance through multi-hop relays. VANET are mainly characterized by a dynamic network topology and a heterogeneous node density due to road traffic conditions.

This paper deals with broadcasting techniques which are used for sending safety messages, traffic information or comfort messages. When a packet is broadcasted, it is received by all nodes within the sender's coverage area (provided that no interference or radio channel trouble occurs). Every receiver will decide to relay or not the packet depending on its own broadcasting strategy. This hop-to-hop communication would lead to a full coverage of the network. Performing an efficient multi-hop broadcast in VANETs is however a difficult task. The protocols should take into account the specificities of the radio channel, the high mobility of nodes and the network density. The decision to relay the packets is taken in a distributed way, but each node's decision has a real impact on the efficiency of the overall dissemination strategy: in high-density networks, too many relay nodes would quickly increase the number of collisions, leading to a saturation of the bandwidth and a significant increase of the latency. On the other hand, if not enough relay tasks are performed in low-density networks the message may not be widely disseminated. Several approaches are proposed in the literature to overcome this problem. Some methods from Mobile Ad hoc Networks (MANETs) use the neighborhood knowledge [13] [11] to choose the best relay nodes. However, the high mobility that characterises VANETs makes their application in such a network very difficult. Some stochastic methods use waiting time to reduce the number of redundant packets [8] [14] [10] [4] [6]. But if this waiting time is not well chosen, it may increase the message dissemination time. The approach we present in this paper is based on the Smart-flooding protocol [1] that uses a genetic algorithm optimization process to dynamically adapt dissemination strategies with respect to the network density.

It is also important to adapt the broadcasting strategy to the priority level of the message. For instance, emergency messages such accident alerts, should be delivered as fast as can be done in the source node's neighbourhood. · Conversely, it does not matter if some weather information with limited impact and less urgent tourist information are broadcasted with a more important latency since there is no emergency.

This paper investigates the problem of building an autonomous and robust broadcasting protocol, which provides each node with the adequate strategy to determine if an incoming message has to be forwarded or not depending on its priority level and the network density. The goal is to make effective use of radio resources when there are many messages to send simultaneously. The paper is organized as follows: Section 2 discusses a state of the art of existing broadcasting methods. Thereafter, Section 3 formulates the broadcasting problem in VANETs as a multiobjective problem and presents an optimization methodology. The proposed Autonomic Dissemination Method (ADM) is detailed in Section 4 and its performances are assessed in Section 5.

2 Related Work

2.1 Broadcasting Protocols

In the literature, ad hoc broadcasting methods are classified into two categories: deterministic and stochastic methods.

2.1.1 Deterministic Methods

Deterministic Methods are those for which the broadcasting process and the behaviour of each node is predictable.

The simplest broadcasting method is the *Simple flooding*. Every packet is relayed exactly once by each node. Thus, in a network consisting of n nodes, n copies of the packet will be sent. A drawback of this method is that it may lead to many useless redundant packets. Another well-known deterministic methods subcategory is made up of *neighbour knowledge-based* protocols. These methods are based on a comparison of lists of neighbours : 1-hop neighbour list for *Distributed Vehicular Broadcast* (DV-CAST) [17] or 2-hop neighbour list for *Scalable Broadcast Algorithm* (SBA) [13]. These lists are included in the broadcast packets so that the receiver (r) can compare the sender's list to its own list. This comparison allows to determine the additional nodes that may receive the message if it is forwarded by r. Among *neighbour knowledge-based* methods, the *Multi-point relay* (MPR) [11] · consists in selecting, for each node, the smallest set of its 1-hop neighbours that will allows connection with all its 2-hop neighbours. If *neighbour knowledge-based* methods can be considered as fairly accurate, their main drawback is their non-applicability in networks with very high mobility, since information about neighbours become inaccurate very quickly.

2.1.2 Stochastic Methods

Stochastic Methods statistically assess the gain that could be obtained if the packets are relayed by a given node. They include *probabilistic schemes* which try to limit the number of relays by setting up the probability for each node to relay the packets. For a given network density, there exists p_s, a threshold value of probability, that would allow all nodes receive the packets, while reducing the number of unnecessary repetitions and causing few collisions. Any other value $p > p_s$ would not lead to better coverage. One challenge is to determine the correct value of p_s.

Smart-flooding [1] is a probabilistic protocol that assigns,among others, to each node · the probability of retransmission and the number of repetitions of each message. This protocol assumes that in some VANET scenarios, a vehicle may have no neighbour when it sends a packet. Therefore, it may be necessary to repeat the packet several times. The parameters introduced by Smart-flooding are optimized using a genetic algorithm. This protocol has the distinction of being robust with respect to the density in the case of sending an emergency message. Smart-flooding inspires for the contribution we present in this paper.

Counter-based methods rely on the assumption that the more a node receives copies of the packet, the less likely it is useful to relay this packet. Upon reception of the first copy, the node initializes a C counter and sets a timeout RAD (Random Access Delay). During the waiting period, C is incremented upon reception of a

copy of the packet. When RAD expires, the packet is relayed if C is less than C_t, a threshold value. Like probabilistic methods, the challenge is to find the right value of C_t. Karthikeyan et al. [8] proposed a protocol that defines two categories of nodes according to their number of neighbours, with respect to a given threshold. Each node decides to relay each packet depending on its own category and the category of the last hop of this packet.

Location-based methods relay messages, depending on the potential additional coverage area that will result from this retransmission. These technique do not consider whether nodes exist within that additional area or not. AckPBSM [14] and POCA [10] use this approach and set lower RAD to nodes that are far from the source (or last-hop relay). In [4], Garcia-Lozano et al. use a continuous expression to compute waiting time in order to reduce the number of collisions. Their method is used for advertising services like gas station location. They benefit form the advantages of distance-based methods in order to effectively use the bandwidth. The authors add some mechanisms to allow their approach to cope with not fully connected networks (for example sparse networks during non-rush hours). They use a store-carry forward mechanism. Our proposed protocol (ADM) handle this issue by repeating (if necessary) some packets many times. We note that Garcia-Lozano et al.'s solution is for an application that convey information that is not critical. In the case of sending emergency messages, this approach could be penalized by the waiting time that could increase the latency.

Bi-Zone Broadcast (BZB) [6] combines probabilistic and distance-based schemes to reduce both the dissemination delay and the overuse of the wireless channel. According to a given threshold (D_{th}) the authors divide the area into two zones: nodes that are close to the source/relay node use a random Contention-Based Forwarding (CBF); nodes that are beyond D_{th} use a distance-based CBF. This leads to ensure that the farthest node has a lower waiting time before forwarding the message. In case there is no node beyond D_{th}, the use of random CBF avoids stopping the broadcast process. In addition, the authors discriminate potential relays based on their capabilities: Road-Side Units (RSUs) and tall vehicles are favoured during the relay selection since they might have better antennas and higher transmission power.

2.2 Autonomic Computing

Traditionally, networks management is a manually controlled process. The creation of self-management systems with limited human interventions was the vision to bring autonomy within IT environment in order to cope with increasing complexity and excessive maintenance costs. Networks become a collection of interconnected self-governed entities where human intervention is limited to high-level directives. The first initiative dealing with this new paradigm is inspired by biological systems and in particular, the autonomic nervous system [5]. Although the objectives list of the self-management concept was extended since 2001 ·, the main objectives for autonomic systems are Self-configuring, Self-optimizing, Self-healing and Self-protecting. To achieve those objectives, autonomic systems have a detailed knowledge of their internal state as well as their environment using a continuous monitoring of eventual changes that could affect their components. Detecting changes induces the autonomic system to adjust its resources and the monitoring

continues to determine if the new measures satisfy the desired performance. That is the closed control loop of self-management systems. This loop is implemented by autonomic managers, which control managed resources using sensors and effectors manageability interfaces [7].

We propose in this paper an autonomic robust broadcasting method taking into account the Autonomic Computing concepts to adapt broadcasting strategies thanks to a knowledge base provided by autonomic mobile nodes (see Section 4)

3 The Broadcasting Problem

3.1 Broadcasting in VANETs: an Optimization Problem

The broadcasting problem in VANETs is known to be NP-hard. Designing an efficient protocol requires to meet several objectives that can be antagonistic: transmitting messages to the maximum of nodes while avoiding the overuse of the radio channel; delivering packets as quickly as possible, knowing that this speed may cause radio interferences. In a nutshell, this is clearly a multi-objective optimization problem for which each solution is a set of parameters that define a broadcasting strategy. This strategy may consist of the following parameters:

- P: the probability to relay every packet. Upon reception of the first copy of a broadcast packet, each node decides to relay it or not, depending on P.
- Nr: the number of repetitions of each packet. In low density networks, when a node sends a packet, it is not unusual that it has no neighbour in its coverage area that will receive the message and relay it. Therefore, it may be necessary to repeat the packet several times.
- Dr: the delay between two successive repetitions. Applicable only if $Nr > 1$. A very short delay could lead to many interferences, whereas a very long delay may slow down the broadcasting process.
- TTL: the Time To Live or the maximum number of hops for each packet. The TTL is used to limit the packets' spread. It could be replaced by any parameter dealing with geographical coordinates or transmission time.

The performance of broadcasting strategies is evaluated using four critera:

- the average number of Collisions (NC).
- the propagation Time (PT). It is the time between the transmission of a packet and the time it is received by all nodes within the area of interest.
- the total number of repetitions of each packet (R).
- the *full reception ratio* (FR). It refers to the guarantee that the packets will be received by all nodes (the reachability).

NC and R enable to measure the radio channel usage: high values indicate that the evaluated strategy is likely to interfere with other communications in the network.

Determining the best broadcasting strategy can be seen as a multiobjective optimization problem that aims to find the solution $\overrightarrow{x}$ (or a solution set $\overrightarrow{X} = \{\overrightarrow{x_0}, ..., \overrightarrow{x_n}\}$) such that:

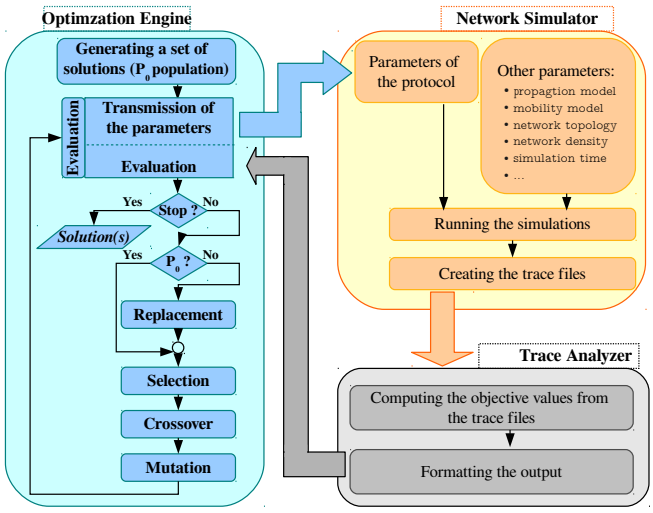


Fig. 1 The flowchart of HOPES

$$\overrightarrow{x} = [P, Nr, Dr, TTL] \; s.t. \begin{cases} NC(\overrightarrow{x}) \; is \; to \; be \; minimized \\ PT(\overrightarrow{x}) \; is \; to \; be \; minimized \\ R(\overrightarrow{x}) \quad is \; to \; be \; minimized \\ FR(\overrightarrow{x}) \; is \; to \; be \; maximized \end{cases}$$

The next section describes the methodology which is used.

3.2 Methodology

The P, Nr Dr and TTL parameters are optimized using HOPES (Hybrid Optimization Platform using Evolutionary Algorithms and Simulations). Our platform combines an optimizer, a network simulator and a trace analyzer. Figure 1 illustrates the interaction of these three modules.

The Optimization Engine is used to effectively explore the search space while the Network Simulator assesses solution using models that are closed to reality. We used aGAME(adaptive Genetic Algorithm with Multiple parEto sets) [2] as optimizer tool. aGAME generates a set of possible solutions. Thereafter, theses solutions are transmitted to the network simulator which integrates them with other parameters in order to better reproduce the context of a real network. The trace files generated during the simulation are then transmitted to the Trace Analyzer module. The latter processes the trace files in order to extract the values of the objective functions (NC, PT, R, and FR) and presents the obtained results according to format required by the genetic algorithm. Then, aGAME uses these results to guide the exploration of the search space. The process is repeated until a stop criterion is met (for instance the total number of solutions to evaluate).

The overall optimization process leads to a set of solutions, corresponding to broadcasting strategies that fit a network with a given density level. This process is repeated for several densities by changing the corresponding parameter in the Network Simulator module. It is worth mentioning that this is an offline optimiza-

tion process. The results (that represents the "best-suited" broadcasting strategy for each density) allow building a knowledge base that establishes a connection between density levels and broadcasting strategies. Each vehicle can therefore choose the appropriate dissemination strategy, depending on the density of the network in which it is located. The evaluation of the density level is discussed in section 4.2.

4 Density and Priority Levels Based Autonomic Dissemination Method

In this paper, we propose an extension of our Smart-flooding protocol thanks to an autonomic robust broadcasting method called ADM (Autonomic Dissemination Method). We adapt the broadcasting strategy used by the Smart-flooding according to, not only the VANET's density level but also the priority level of the message to disseminate. Indeed, ADM is based on the closed control loop implemented by an autonomic manager within a mobile node (vehicle).

4.1 Architecture

We adopt the self-management characteristics to improve robustness of Smart-flooding. Indeed, each node is considered as an autonomic element thanks to an autonomic manager that enables broadcasting decisions making according to environment changes in terms of density level (see Section 4.2) and takes into account message priority level (see Section 4.3). To achieve these goals, the autonomic manager implements the MAPE-K closed control loop (see Figure 2) and communicates with the mobile node (called managed resource) using sensors and effectors manageability interfaces.

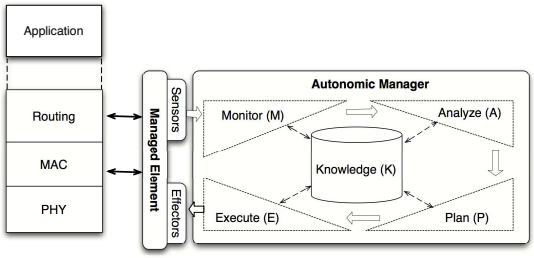


Fig. 2 Autonomic manager closed control loop

Each autonomic node within a VANET provides the Monitor function (M) of the autonomic manager with network traffic information's thanks to the Sensors manageability interface. In the context of the novel ADM protocol, the Monitor determines if the received packet is a broadcasting one thanks to its destination address. If so, the Monitor provides the Analyze function (A) with this information to follow the control loop process. The Analyze function has to determine, not only the priority level of the message according to the header information's, but also the current density level of the node environment thanks to the node local view table

stored within the Knowledge base (K). After density level evaluation (detailed in Section 4.2), the Plan function (P) uses the density and priority values provided by the Analyze function to retrieve the adequate broadcast strategy from the Knowledge base thanks to the strategy table created by the offline optimization phase (see Section 3.2). Then, the Plan function provides the Execute function (E) with the broadcasting parameters (P, Nr, Dr and TTL) in order to change the behavior of the mobile node managed resource by executing the corresponding broadcast strategy actions thanks to the Effectors manageability interface.

4.2 Density Level Evaluation

ADM evaluates the local density for each autonomic node based on the number of active neighbours from which it received · packets. During communication, each node builds a view of its neighbourhood based upon· the neighbour list having transmitted or relayed packets. Each autonomic node maintains a history in which it associates with each received packet a list of nodes having sent or relayed it. Upon receipt of the first copy of a packet, its identifier and the source/relay address are recorded within the autonomic manager Knowledge base in a · local view table. When a redundant copy is received, the identifier of the new relay is · appended to list of addresses (L) corresponding to the packet. L is stored in the local view table. Each address is recorded only once for each packet. The current number of neighbours ($\overline{N_i}$) for each i autonomic node is equal to the average number of transmitters for all the packets stored in L (see Equation 1).

$$\overline{N_i} = \frac{\sum_{j=1}^{n} |L(j)|}{n} \tag{1}$$

where n is the number of packets in the local view table and $|L(j)|$ the number of nodes that issued / relayed the j^{th} packet in the table.

4.3 Priority Levels

The messages' importance in VANETs leads to different priorities with particular requirements. Introducing priority in broadcasted message has been investigated in [16].

In this paper we focus on three priority levels for broadcasted messages in VANETs and we define for each level a broadcast policy to satisfy. The goal here is to highlight the capability of ADM to adapt to the messages contents. These priority levels could be easily redefined or extended.

– High-priority Level messages (HL), e.g. safety message or accident detection. They have to be delivered as quickly as possible since they may require a prompt reaction from the driver. For these messages, our protocol tries to minimize the required propagation time, then to maximize the full reception ratio.

– Medium-priority Level messages (ML), e.g. traffic report. They suppose less-critical information, where the driving reflexes are not part of the equation and only attention is required. They should widely cover the network while reducing the number of collisions.
– Low-priority Level messages (LL), e.g. weather information, tourist attraction or point of interest. They are optional messages whose delivery must not alter the delivery of higher-priority messages. The use of the radio resources has to be optimized, though reducing the number of collisions as well as the number of retransmissions, for an acceptable node coverage ratio.

5 Experiments and Results

· In this section, we particularly look at the behaviour of · ADM when the traffic load increases (many packets transmitted simultaneously). Due to a lack of space, we will not discuss the robustness of ADM when varying the network density.

The simulations were carried out using the ns2 network simulator (2.34 version), with Shadowing Pattern propagation model [3]. It is a realistic and probabilistic propagation model which can produce statistical errors distributions, such as slow and fast fading, while being easy enough to be carried out on medium to large simulations.

Regarding the topology model, we considered a convoy of vehicles lined up on 10 kilometers. To illustrate different density levels, we varied the inter-vehicle distance. Table 1 shows the parameters of the topology used for different levels of density.

Density levels	Number of vehicles	Inter-vehicle distance	Number of neighbours
High (Urban)	400	25 m	26
Medium (Suburban)	134	75 m	10
Low (Highway)	50	200 m	5
Very low (Rural)	10	1000 m	1

Table 1 Topology parameters for different density levels

The scenario of a very low-densty network illustrates inter-vehicle communications in rural areas. In these areas, vehicles rarely pass each other. Therefore they often have a few neighbours (if any). To represent such an environment, the *Shadowing pattern* propagation model has been tuned so that each vehicle can communicate only over 20% of the total simulation time. This corresponds roughly to a network with 10 vehciles lined up on 10 kilometers with an inter-vehicle distance of 1000 meters if the (classical) Shadowing propagation model is used.

Depending on the considered scenario (see Table 1), each vehicle may have an average number of neighbours which varies from 1 to 26. Indeed, using WiFi, the broadcast packets are received over long distances (up to several hundred meters, even 1 km [15]). Since all messages are sent simultaneously and propagate in a very short time, the mobility model is not relevant. Indeed, the propagation time is less than 1 second. This situation prevents the network topology to significantly change during communication.

5.1 Broadcasting Prameters Values for Each Priority Level

To determine the parameters of ADM for each priority level in various density networks, we used the HOPES platform (see Section 3.2). Like in most of multi-objective problems, the optimization process returns as a result several potential solutions which offer a compromise between the different objective functions (NC, PT, R, FR). To refine the results, we used a multiple-criteria decision-making approach based on preferences.

For sending high-priority messages, we select the solution which allows to deliver packets as quickly as possible while covering the largest number of nodes in the network. For medium-priority messages, the first criterion taken into account is the reachability (FR), then, among the solutions that have a FR value almost equal to 1 (the maximum), we select the one which causes the least collision. And finally, for the low-priority messages, the goal is to send packets while slightly using the wireless channel. The first and second criteria are respectively NC and R. The broadcasting parameters for the three priority levels and the objective functions values corresponding to various density levels are presented in Tables 2 to 5, respectively for high, medium, low and very low-density networks. For each scenario, we use one source node located at the end of the convoy of vehicles. Scenarios with multiple source nodes are discussed in Section 5.2.

	Broadcasting parameters					**Performance Results**			
Message Classes	P	Nr	Dr	TTL		NC	PT	R	FR
High-Level (HL)	0.329	1		32		497	0.051	131	99.6%
Medium-Level (ML)	0.258	2	1.721	15		347	0.1063	207	100%
Low-Level (LL)	0.188	1		39		190	0.048	75	86.8%

Table 2 ADM Parameters and Performance Results for a High-density Network (the Urban Scenario)

In high-density networks, the probability to relay the packets is low (see Table 2). When Nr is equal to 1, the Dr cell (the delay between successive repetitions) has been darkened since this parameter is only applicable when $Nr > 1$. For high-priority messages (in the high density network), relaying each packet only once, with a probability of about 0.3 allows rapid dissemination of the message. However, this probability value generates a large number of collisions. This drawback is mended for medium-priority level messages. To reduce the number of collisions and increase the reachability (FR), we selected a solution with a lower probability and a number of repetitions equal to 2. Moreover, as the repetitions are not made in burst the risk of interference is reduced.

For low-priority level messages, it is worth noting that the results only concern the packets that have been received by all vehicles. In other words, 86.8% of packets that are received spread quickly (due to low competition in the access to the radio channel), but 13.2% of them are not completely delivered.

Following the same reasoning, we obtain the broadcasting parameters for sub-urban and highway scenarios (Tables 3 and 4 respectively).

For the scenario of the rural area, the low density level of the network implies the need to retransmit each packet many times (see Table 5). Indeed, in this scenario, VANETs behave like delay tolerant networks (DTNs) [12]. In such a

	Broadcasting parameters				Performance Results			
Message Classes	P	Nr	Dr	TTL	NC	PT	R	FR
High-Level (HL)	0.776	1		26	166	0.044	104	100%
Medium-Level (ML)	0.519	2	0.951	16	93	0.121	139	100%
Low-Level (LL)	0.291	2	0.276	27	35	0.209	82	75.8%

Table 3 ADM Parameters and Performance Results for a Medium-density Network (the Suburban Scenario)

	Broadcasting parameters				Performance Results			
Message Classes	P	Nr	Dr	TTL	NC	PT	R	FR
High-Level (HL)	0.999	4	1.147	40	31	0.092	199	100%
Medium-Level (ML)	0.916	2	0.729	28	24	0.124	90	100%
Low-Level (LL)	0.649	2	1.933	34	10	1.414	66	82.8%

Table 4 ADM Parameters and Performance Results for a Low-density Network (the Highway Scenario)

context, since the radio channel is rarely used, even if ADM is able to differentiate broadcasting strategies according to the class of a message, in practice these classes scarcely impact the communication process. The main constraints that must be met are: having a probability P close to 1 and a high number of repetition Nr.

	Broadcasting parameters				Performance Results			
Message Classes	P	Nr	Dr	TTL	NC	PT	R	FR
High-Level (HL)	0.833	28	0.233	28	58	13.09	1167	99.8%
Medium-Level (ML)	0.896	25	1.468	34	16	28.295	1124	100%
Low-Level (LL)	0.902	8	1.622	19	4	30.957	362	92.6%

Table 5 ADM Parameters and Performance Results for a Very Low-density Network (the Rural Area Scenario)

5.2 Performance evaluation

To assess the performance of ADM with respect to Simple flooding and Smart-flooding [1] methods, we considered the suburban scenario. Similar results are obtained for the other scenarios, but they are not presented in this article due to a lack of space.

Let us recall that the design of ADM had three major goals. ($g1$) swiftness: delivering of high priority messages as soon as possible; ($g2$) network coverage: reaching the maximum nodes for medium-priority messages; ($g3$) effective use of radio channel for low priority messages. These objectives must be met even if the traffic load increases (for instance when messages are sent simultaneously). To better measure the achievement of these goals, we also report on the results' figures, the performance of *Simple flooding* and *Smart-flooding* protocols, for reference.

We vary the number of source nodes from 3 to 30. With 30 source nodes in a convoy of vehicles over 10 km, a message is issued approximately every 330 $meters$. Taking into account the communication range (for broadcast messages), each node may have within its coverage area 4 or 5 neighbours which simultaneously issue

a message. At the second and third hop, the number of simultaneously issued messages, within each node's coverage area, greatly increases. This may tend to quickly congest the radio channel.

Regarding the propagation time, ADM aims to deliver high-priority messages (denoted ADM_{HL}) as fast as can be done, whatever the number of source nodes. Figure 3 shows that the performances of ADM meet the first goal ($g1$). Compared to *Smart-flooding* and *Simple-flooding*, ADM is less sensitive to the number of sources than the other two protocols. Ultimately, even with 30 source nodes, the average delay of priority messages is less than 250 ms (for a 10 km line), which is acceptable. It is worth recall that the driver reaction time to traffic warning signals can be in order of 700 ms [9].

The goal $g2$ is assessed in Figure 4 which shows the delivery ratio. A packet is considered as "delivered" if it is received by all nodes. Medium-priority packets (ADM_{ML}) are always received by all nodes. ADM_{ML} ensures this result because

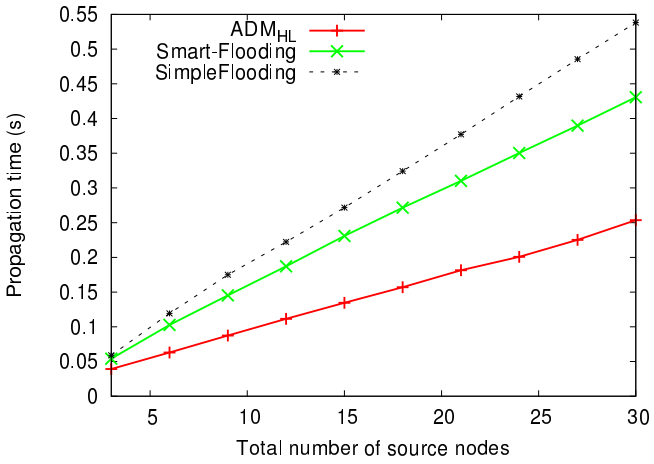


Fig. 3 Propagation time

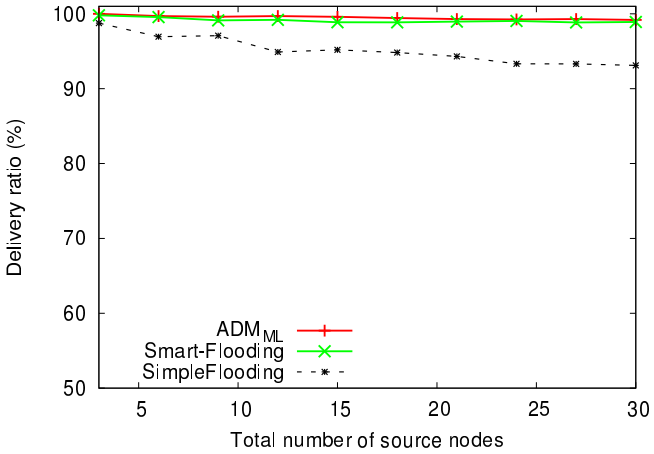


Fig. 4 Delivery ratio

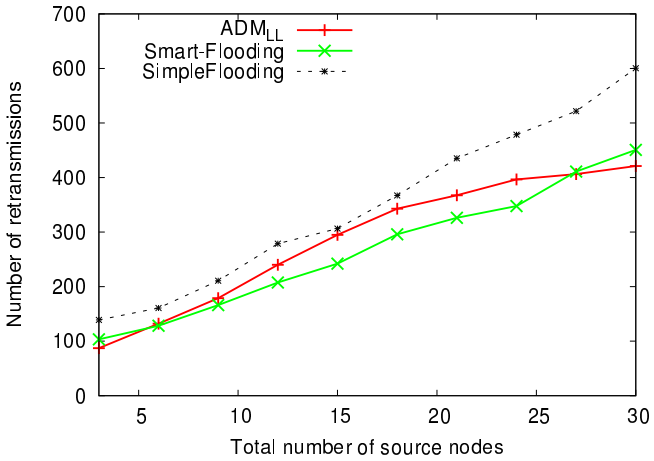


Fig. 5 Number of retransmissions

it slightly increases the probability of retransmission (see Table 3). It should be noted that if the value had been greatly increased, the performance of ADM would be degraded and would get close *Simple flooding*'s results.

And finally, Figures 5 and 6 show that our third goal ($g3$) is met: the low-priority messages use little radio channel by limiting the total number of repetitions for each packet (Figure 5). In addition, the fact that two potential successive repetitions of the same packet are spaced out (Dr value in Table 3) reduces the number of collisions (Figure 6).

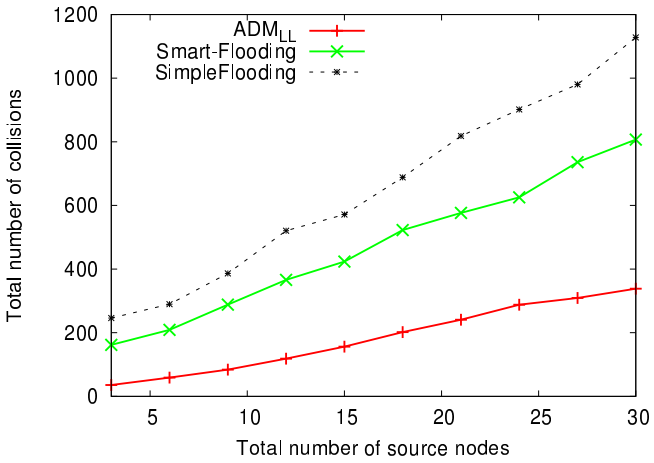


Fig. 6 Number of collisions

For a fair comparison, we also compare ADM to *Smart-flooding* and *Simple flooding* regarless the message priority levels. This means the results of ADM in these simulations (see Figures 7 and 8) correspond to the average for all the messages (all priorities levels combined).

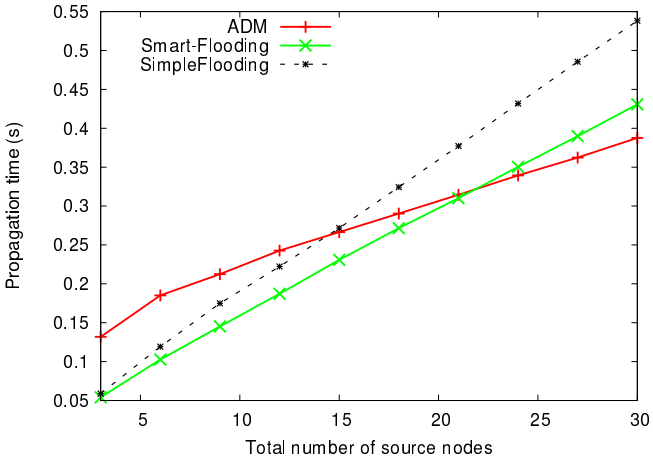


Fig. 7 Propagation time: ADM all priorities levels combined

Figure 7 shows that if we consider the average delay of all packets, the overall performance of ADM is very interesting when the load of the radio channel is high (many source nodes). This is explained by the key principle of ADM: when a packet's priority level is not high, ADM favors broadcasting strategies that avoid overusing the radio channel. Thus when there are many concurrent access to the radio channel (many source nodes), *Smart-flooding* and *Simple flooding* cause many collisions. Therefore the packets' propagation is slowed down. This is corroborated by Figure 8 which shows that the number of collisions when using ADM is lower than the other two flooding methods.

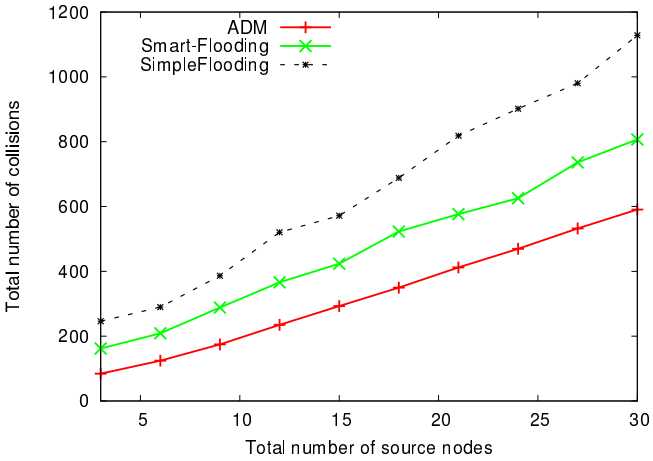


Fig. 8 Number of collisions: ADM all priorities levels combined

6 Conclusion

This paper introduced an autonomic dissemination protocol (named ADM) that adapts broadcasting strategies to both network density and message priority level. This protocol relies on a genetic algorithm to optimize broadcasting strategies and Autnomic Computing concepts to adapt communication parameters according to the network context. The simulations results reveal the scalability of ADM on a short-term period when the number of simultaneous transmissions significantly increases. These results also show that ADM outperforms two other broadcasting methods: the Smart-flooding protocol and the simple flooding method. As an ongoing work, we are currently evaluating ADM performances when the network density level changes over the time. The aim is to establish the reliablity of ADM over a long communication period for various mobility models.

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