Proposed Message Transit Buffer Management Model for Nodes in Vehicular Delay-Tolerant Network

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Summary

This study is situated in the context of intelligent transport systems, where in-vehicle devices assist drivers to avoid accidents and therefore improve road safety. The vehicles present in a given area form an ad' hoc network of vehicles called vehicular ad' hoc network. In this type of network, the nodes are mobile vehicles and the messages exchanged are messages to warn about obstacles that may hinder the correct driving. Node mobilities make it impossible for inter-node communication to be end-to-end. Recognizing this characteristic has led to delay-tolerant vehicular networks. Embedded devices have small buffers (memory) to hold messages that a node needs to transmit when no other node is within its visibility range for transmission. The performance of a vehicular delay-tolerant network is closely tied to the successful management of the nodes' transit buffer. In this paper, we propose a message transit buffer management model for nodes in vehicular delay tolerant networks. This model consists in setting up, on the one hand, a policy of dropping messages from the buffer when the buffer is full and must receive a new message. This drop policy is based on the concept of intermediate node to destination, queues and priority class of service. It is also based on the properties of the message (size, weight, number of hops, number of replications, remaining time-to-live, etc.). On the other hand, the model defines the policy for selecting the message to be transmitted. The proposed model was evaluated with the ONE opportunistic network simulator based on a 4000m x 4000m area of downtown Bouaké in Côte d'Ivoire. The map data were imported using the Open Street Map tool. The results obtained show that our model improves the delivery ratio of security alert messages, reduces their delivery delay and network overload compared to the existing model. This improvement in communication within a network of vehicles can contribute to the improvement of road safety.

Keywords:
Vehicular delay-tolerant networks, Transit buffer, Buffer management models, Security alert message

1. Introduction

Road accidents are becoming more and more frequent in the world. They result in numerous deaths and enormous material damage. According to the WHO (World Health Organization) report, road accidents cause an average of 1.24 million deaths per year worldwide [1]. These disastrous consequences of road traffic accidents have very important socio-economic impacts on development, due to a loss in productivity and income. Indeed, it is the youngest and most economically productive population that is most affected by road traffic accidents.

In order to remedy these serious consequences of road accidents, researchers have developed Intelligent Transportation Systems (ITS) [2]. ITS are composed of sensors, communication devices, etc., which allow nodes to detect situations that may cause accidents and alert drivers. In the context of vehicular communication, these ITS devices are embedded in vehicles. Vehicular Ad-Hoc Networks (VANETs) are vehicular networks in which mobile nodes communicate directly with each other [3]. However, in an environment of low node density or sparse nodes, VANETs are no longer reliable. Indeed, they suffer from frequent disconnections, resulting in data loss, long or variable transmission delays [4]. In order to cope with these problems (data loss, lack of connectivity, etc.), VDTNs (Vehicular Delay-Tolerant Networks) that use the nodes' buffer memory have appeared [5]. Indeed, vehicles store messages in their buffer for varying lengths of time, carry them, and then transmit them to the final destination or intermediate nodes when a communication opportunity arises [4][6].

VDTNs can be used to provide safety applications that generate alert messages such as accident warnings, road condition warnings, animal crossings, etc. They also offer applications of various kinds that generate messages of cooperative driving, dissemination of commercial information, connectivity of remote areas, etc. All these applications are contained in the reports of the Vehicle Safety Communications Project (VSCP) elaborated in the United States in 2005 [7] and that of the European Telecommunications Standards Institute (ETSI) elaborated in 2009 [8]. These two reports allow a classification of applications into three main classes which are road safety applications, road traffic management applications and entertainment and comfort applications. The messages from the various applications are prioritized into three priority service classes [9]. Thus, messages from road safety applications are high priority alert messages.

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Messages from traffic management applications are medium priority messages. And those from entertainment and comfort applications are low priority messages.

Typically, node buffers are small. However, not only do nodes have to store messages of all priority classes destined for the node, they also have to relay messages destined for other nodes in the network. Therefore, if the buffer is full and a security alert message arrives at the buffer, the message(s) to be deleted from the buffer must be determined in order to insert the alert message. In addition, when transferring messages, it is necessary to determine the message to be selected during opportunistic encounters in order to improve road safety. Therefore, the transit buffer management model to be implemented to better ensure road safety must be determined.

Recently, in VDTN, the authors [10] proposed a model for buffer management based on the message weight. The expression of the message weight is given by:

$$P_1[i] = NH_i + NR_i + \frac{1}{S_i} + \frac{1}{RTTL_i} + \frac{1}{TB_i} + \frac{1}{P_i}. \qquad (1)$$

With $i \in \{1, 2, 3,.., n,..\}$ $P_i \in \{1, 2, 3\}$ (2)

In this equation, NH_i is the number of message hops, NR_i is its number of replications, S_i is its size, $RTTL_i$ is its remaining time-to-live, TB_i is the time spent in the buffer, and P_i is its priority service class.

The expression $P_1[i]$ was obtained by integrating the priority service class (Pi) into the message weight expression $P_2[i]$ defined in [11].

The expression of the weight $P_2[i]$ is given by:

$$P_2[i] = NH_i + NR_i + \frac{1}{S_i} + \frac{1}{RTTL_i} + \frac{1}{TB_i}. \qquad (3)$$

With $i \in \{1, 2, 3,.., n,..\}$ (4)

However, when we set the value of the priority class (Pi) to zero in the expression of $P_1[i]$ given in [10], we get an infinite value of the message weight instead of finding the message weight expression $P_2[i]$. Therefore, it is necessary to propose a new expression of the message weight considering the priority service class in order to guarantee the support of various applications with different requirements.

In this paper, we propose a new buffer management strategy based on a new message weight expression to improve road safety. Our main contribution is as follows:

We propose a model for managing the message transit buffer of nodes in a vehicular delay tolerant network. This model consists in setting up, on the one hand, a drop policy for messages in the buffer when the buffer is full and must receive a new message. This drop policy is based on the concept of intermediate node with respect to the destination, queues and priority class of service. It is also based on the properties of the message (size, number of hops, number of replications, remaining time-to-live, priority class of service, time in the buffer). On the other hand, the model takes into account the scheduling policy for the selection of messages to be transmitted.

This paper is organized as follows: section 2 presents a literature review, section 3 presents the new buffer management strategy and finally, section 4 presents the conclusion and perspectives.

2. Literature Review

In the literature, several buffer management models have been developed. These models aim at identifying the message(s) to be dropped when the buffer is full and needs to receive a new message on the one hand and on the other hand at ordering the messages in the buffer in order to select the message to be transferred during opportunistic encounters.

Recently, in [12], the authors have developed a buffer management model based on the message weight expression given in [10]. This model improves the overall network performance in terms of increasing the message delivery ratio of all priority classes of service, reducing the network overhead, and reducing the average delivery delay of high priority messages. However, in this model, the obtained curves of the message delivery ratio by priority class as a function of the buffer capacity on the one hand and as a function of the number of vehicles on the other hand, present practically the same curves. Therefore, in this study, the priority service class does not really impact the message delivery ratio.

In [13], the authors proposed a buffer management strategy called DFS (Dropping- Forwarding-Strategy) that uses the number of message copies, the maximum number of forwarded messages determined from a list of the number of nodes that have received a copy of a message, the time-to-live, the inter-contact time and the encounter-time. This information is aggregated into a multi-objective utility function to determine which messages to forward and which to discard during the encounter-time. Evaluations have shown that this strategy provides improved delivery ratio, reduced network overhead, and reduced message delivery delay compared to existing models. However, this strategy is independent of the priority class of service, therefore security alert messages that require low delivery delay have the same delay as traffic management or entertainment messages.

In [14], the authors proposed a memory management scheme to improve the performance of PRoPHET [15] and Spray-and-Wait [16] routing protocols. In this system, the scheduling policy is based on the number of copies of the message, its size and time-to-live which allows the selection of the message with the highest weight on the one hand and on the other hand the drop policy based on the size of the message, its time-to-live and number of copies which allows the deletion of the message with the highest weight. This multi-criteria management system allows an increase in the delivery ratio and a reduction of the network overload, but cannot reduce the message delivery delay.

Similarly, in [17], the authors proposed a model that combines the delivery predictability of the PRoPHET routing protocol [15], the copy limitation of the Spray-and-Wait routing protocol [16], and a buffer management scheme. This buffer management system is based on a CCM (Congestion-Control-Metric) that combines the delivery probability estimate, the time-in-node metric and the memory overhead ratio. Thus, in case of buffer congestion, the message with the lowest CCM value is dropped. As for scheduling, it allows the selection of the message with the highest CCM value. This model allows an improvement of the message delivery ratio and a reduction of the network overload. However, it does not reduce the message delivery delay and does not take into account the priority class of service.

These different multi-criteria buffer management systems outperform single-criteria buffer management systems in terms of improving delivery ratio, reducing network overhead, and reducing delivery delay. Based on the strengths of these buffer management systems and improving the weaknesses, we propose a new buffer management strategy.

3. Proposed Buffer Management System

In this section, we propose a message weight expression and a particular queueing organization of a node's buffer. Subsequently, we present our dropping policy, our scheduling policy, and then our buffer management system which consists of the two previously presented policies.

3.1 Expression of the message weight and the constitution of the queues

As in [10], we propose a buffer subdivided into two queues according to the weight of each message and the average weight of all messages contained in the buffer.

This message weight is given by the following expression:

$$W[i] = \frac{1}{NH_i} + \frac{1}{NR_i} + S_i + RTTL_i + TB_i + P_i. \quad (5)$$

With $i \in \{1, 2, 3,.., n,..\}$ $P_i \in \{1, 2, 3\}$ (6)

Where NH_i is the average number of hops of message i, NR_i is the number of replications of message i, S_i is the size of message i, $RTTL_i$ is the remaining time-to-live of message i, TB_i is the time put in the buffer by message i, and P_i (P_i {1,2 , 3}) is the priority value of the priority class of message i.

Under these conditions, when $P_i = 1$ the message is of low priority, when $P_i = 2$ the message is of medium priority and when $P_i = 3$ the message is of high priority [9].

The average weight of all messages is given by the following equation:

$$W_M = \frac{1}{N(t)} \sum_{i=1}^{N(t)} W[i]. \quad (7)$$

Where N(t) is the total number of messages in the node's buffer at time t and W[i] is the weight of a message i in the buffer.

As mentioned in the previous section, the buffer is subdivided into two parts. This subdivision of the buffer is based on the weight of the message and the average weight of all messages in the buffer.

Thus, if the message weight is greater than the average weight given by the following inequality:

$$W[i] \geq W_M. \quad (8)$$

The message is placed in the high-weight-queue (HWQ) consisting of recent messages.

On the other hand; if the weight of the message is less than the average weight given by the following inequality:

$$W[i] < W_M. \quad (9)$$

The message is placed in the low-weight-queue (LWQ) consisting of old messages.

Considering the constitution of the queues and their characteristics, in the following, we propose the drop and scheduling policies.

3.2 Proposed drop policy

The proposed drop policy is based on the one developed in [10]. It is based on two concepts, namely: the position of the intermediate node with respect to the destination and the selection of old messages from each of the two queues. In the following, we characterize each of the concepts and then present the proposed dropout policy.

Characterization of the node's position with respect to the destination.

Consider Δ the set of positions occupied by nodes in the network and not containing the position of the destination D at time t.

The position of a node M, closest to the destination D is characterized by the following expression:

$$d_0 = d(D,\Delta) = \min_{M \in \Delta} \| D - M \| \quad (10)$$

Therefore, the position of a node M that is far from the destination is characterized by the following inequality:

$$d(M,D) > d_0 \quad (11)$$

Characterization of old messages by queue

As noted above, the buffer is subdivided into two queues, one of which is high-weighted with recent messages and the other low-weighted with old messages. In our model, the drop policy may require dropping old messages from each of the queues. Therefore, we characterize them as follows:

- In an LWQ, a message M is older than a message N, if the weight of message M is less than the weight of message N. This is given by the following inequality :

$$P[M] < P[N] \quad (12)$$

- In an HWQ, a message M is older than a message N, if the remaining time-to-live of message M is less than the remaining time-to-live of message N. This is translated by the following inequality :

$$RTTL_M < RTTL_N \quad (13)$$

Activity diagram of the proposed Drop Policy

Our message dropping algorithm depends on the elements we have just defined. Namely the position of the intermediate node with respect to the destination and the selection of old messages in each of the queues. Therefore, based on these elements, we are going to explain, using the activity diagram, how the message dropping is done.

Thus, when a new message of any priority class (P_i) arrives at the node's buffer, it is inserted into the buffer if its size is less than the buffer free space (S_{FS}). On the other hand, if its size is greater than the size of the buffer's free space and less than the sum of the sizes of the buffer's free space and the LWQ, the messages in the LWQ are deleted according to their increasing weight until it is inserted.

On the other hand, if the size of the new message of priority class Pi is greater than the size of the buffer free space and greater than the sum of the sizes of the free space and the LWQ, two situations are possible depending on whether the current node is a destination node or an intermediate node. For this purpose, if the current node is not an intermediate node, all the messages of the LWQ are deleted, then those of the HWQ according to their increasing time-to-live, until the new message is inserted.

On the other hand, if the current node is an intermediate node that is far from the destination of the message and if this message has a high priority, all the messages in the LWQ are deleted, followed by those in the HWQ that are less recent than this incoming message.
This activity diagram in Fig. 1 illustrates our drop policy

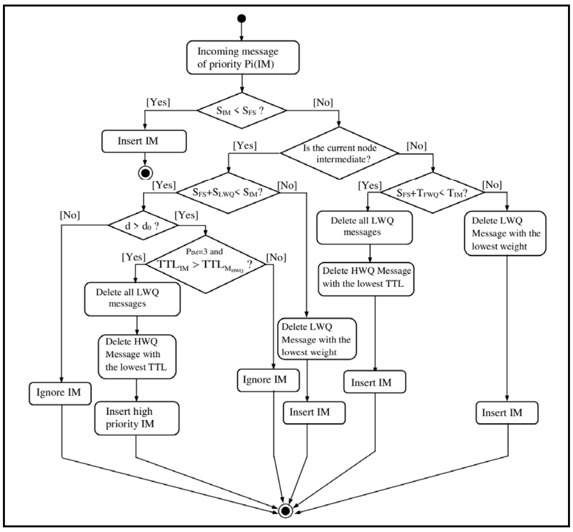

Fig. 1 The activity diagram of the proposed drop policy.

3.3 Proposed scheduling policy

As mentioned above, the buffer is subdivided into a high-weight queue consisting of recent messages and a low-weight queue consisting of old messages. Our scheduling policy, based on the message weight, follows the same principles as the policies developed by the authors in [10] [11]. Thus, during opportunistic contacts, the most recent message is selected for transmission. In the following, we give the characteristics of the recent message and then the activity diagram of the scheduling policy.

Characterization of the most recent message to be selected

In our model, a message N is more recent than another message M whatever the queues if the weight of the message N is greater than the weight of the message M. This translates into the following inequality:

$$P[N] > P[M] \quad (14)$$

Activity diagram of the proposed scheduling policy

Our planning algorithm will depend on the characteristics of the new message to be selected that we have just defined. Therefore, based on this concept, we will explain using the activity diagram how the scheduling is done.

In this model, messages are prioritized from the HWQ consisting of recent messages to the LWQ consisting of old messages. During opportunistic contacts, the message with the highest weight is selected for transmission. However, if two messages have the same weight, the message with the higher priority class is selected for transmission. This activity diagram in Fig. 2 illustrates our scheduling policy

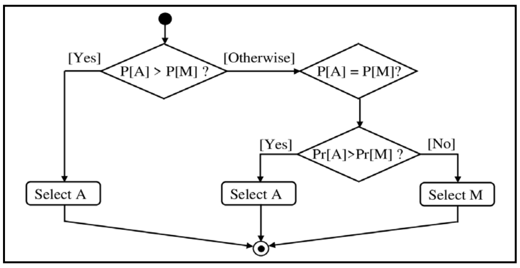

Fig. 2 The activity diagram of the proposed scheduling policy.

3.4 Activity diagram of the proposed buffer management system

The proposed buffer management system is triggered by a message of any priority class entering the buffer. Thus, if the buffer is full or it cannot accommodate the new message of any priority class, the drop policy proposed in section 3.2 is implemented. On the other hand, if the node's buffer is not empty, then the scheduling policy proposed in section 3.3 is implemented. This activity diagram in Fig. 3 illustrates our buffer management system

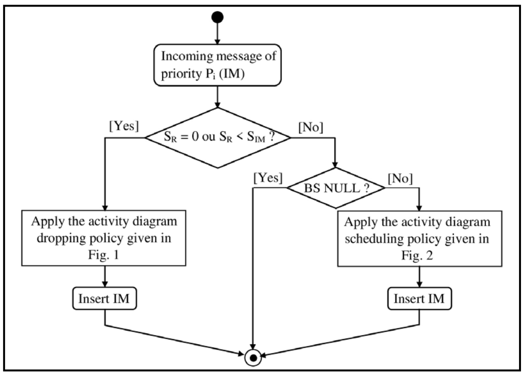

Fig. 3 The activity diagram of the proposed buffer management system.

4. Evaluation of the proposed buffer management system

In this section, we present the set of performance evaluation tools we used, then the different settings made for our simulations, and finally, we present the evaluation results and discussions. These results focus on the impact of the buffer size on the performance of the network on the one hand and on the other hand, on the impact of the variation of the number of vehicles on this performance.

4.1 Performance evaluation tools and simulation settings

Performance evaluation tools

Our model was evaluated using the opportunistic network simulator named ONE (Opportunistic Network Environment) [18] and the *PRoPHET* routing protocol [15]. We use the buffer management system named Factor [19] for a performance comparison. Factor is based on the priority class of service and the message time-to-live. During congestion, it drops the low TTL message. During opportunistic contacts, the message with the highest priority and time-to-live is selected for transmission.

In this study, we use three performance criteria to evaluate the performance of the models. These criteria are:

- The delivery ratio per priority class which determines the number of delivered messages of a priority class (N_D) relative to the total number of messages of that priority class (N_T) created at the source. It is given by the following equation:

$$\tau_L = \frac{N_D}{N_T} \quad (15)$$

- The average delivery delay per priority class represents the average time required by the message of a priority class from the time of its creation to the time of its delivery to the destination. It is given by the following equation:

$$t_M = \frac{\sum_{i=1}^{N_D}(t_{Di} - t_{Ci})}{N_D} \quad (16)$$

  Where t_{Di} and t_{Ci} are the delivery date and creation date of the ith message of priority Pi, respectively.

- The network overhead ratio represents the ratio of the difference between the number of relayed messages (N_R) and the number of delivered messages (N_D) by the number of delivered messages. It is given by the following expression:

$$\tau_{SR} = \frac{N_R - N_D}{N_D} \quad (17)$$

Simulation settings

In our model, following the example of the model proposed in [10], we use as simulation area the city center of Bouaké in Côte d’Ivoire. Moreover, all messages of each of the three priority classes are generated by three event generators. We assume that high priority alert messages generate large volumes of traffic. Thus, they have a size between [750 KB; 1.5 MB] and priority value P = 3, medium priority ones have a size between [250 KB; 750 KB[and priority value P = 2 and finally, low priority ones have a size between [100 KB; 250 KB[and priority value P = 1. The different settings are grouped in Table 1 below.

Table 1: Simulation parameters and their values

parameters	values
Simulation time	12 hours
Simulation area	4000m × 4000m
Number of nodes	25-50-100-150
Buffer size	25 MB - 50 MB
Transmission rate	6 Mbps
Transmission range	30 m
Random speed	30-50 km/h
Message TTL	120 minutes
Waiting time	600-900 seconds
Creation interval	15-30 seconds
Message size	100KB-1.5MB
Mobility model	Shortest-path map-based movement

4.2 Results and discussions

First, for our model and Factor, we vary the buffer from 25 MB to 50 MB. For each of the buffer sizes, we set the number of vehicles to 25 and then to 50. For each of the buffer sizes, we run a batch of 30 simulations using the random seeds. We obtain the results of delivery ratio by priority class and network overhead.

Subsequently, for both models, we set the buffer capacity to 50 MB, then vary the number of vehicles to 25, 50, 100, and then 150. For each number of vehicles, we run a batch of 30 simulations using the random seeds.

We obtain the results of delivery ratio by priority class, delivery delay for high priority messages, and network overhead.

Results of varying the buffer size from 25 MB to 50 MB

Evaluation of the delivery ratio for 25 vehicles

For each of the two model simulation batches, we determine the average message delivery ratio by priority class. These results of average delivery ratio by priority class are collected in Table 2.

Table 2: Average delivery ratio by priority class of our model and Factor for 25 vehicles of 25 MB and 50 MB buffer capacity.

Priority class	**Buffer management systems**	**25 MB**	**50 MB**
Low priority	Factor	6,20	22,33
	Our Model	38,23	41,97
Medium priority	Factor	18,63	49,48
	Our Model	39,80	51,99
High priority	Factor	49,70	61,09
	Our Model	53,82	64,51

Fig. 4 represents the delivery ratio of high priority, medium priority and low priority messages when the buffer size varies from 25MB to 50MB for our model and that of Factor when the network contains 25 vehicles.

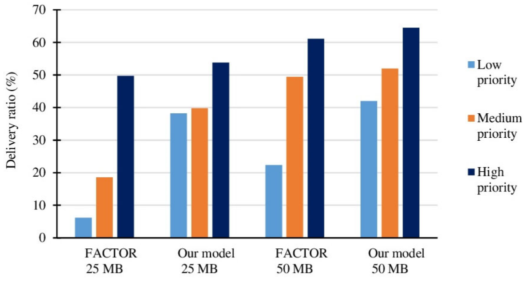

Fig. 4 Message delivery ratio by priority class as a function of buffer size for 25 vehicles.

. When the buffer size varies from 25 MB to 50 MB, our model achieves higher delivery ratio per priority class (38% and 65%) than Factor (6% and 61%). Therefore, our model performs better in terms of delivery ratio per priority class than Factor. This is because our weight-based model favors the transfer of messages of all priority classes unlike Factor which favors only high priority messages. However, if we consider the buffer sizes, we notice that Factor performs better with the 50MB buffer than with the 25MB buffer regardless of the priority class.

Indeed, for low priority messages, Factor allows us to go from a 6.2% delivery ratio with a 25MB buffer to a 22.33% delivery ratio, i.e. an increase in delivery ratio of 260%, against an increase of 38.23% (delivery ratio between 38.23% and 41.97%) in the case of our model when the buffer size varies from 25 MB to 50 MB.

For medium priority messages, Factor allows us to go from a delivery ratio of 18.63% with a capacity of 25MB to a delivery ratio of 49.48%, i.e. an increase in delivery ratio of 165.6%, against an increase of 30.6% (delivery ratio between 39.8% and 51.99%) in the case of our model when the buffer size varies from 25 MB to 50 MB.

And finally, for high priority messages, Factor allows an increase in delivery ratio of 22.9% (ratio between 49.7% and 61.09%) against an increase of 19.9% (ratio between 53.82% and 64.51%) for our model when the buffer size varies from 25 MB to 50 MB.

Evaluation of the network overload for 25 vehicles

Similar to the delivery ratio evaluation, for each of the simulation batches, we determine the average network overload ratio. The results of the average network overload ratio for 25 vehicles with 25 MB and 50 MB buffer capacities are shown in Table 3.

Table 3: Average network overload ratio of our model and Factor for 25 vehicles of 25 MB and 50 MB buffer capacity.

	Buffer management systems	25MB	50 MB
Network overload ratio	Factor	44,29	29,37
	Our Model	22,30	23,72

Fig. 5 shows the impact of buffer size on the network overhead ratio for our model and Factor when the network consists of 25 vehicles.

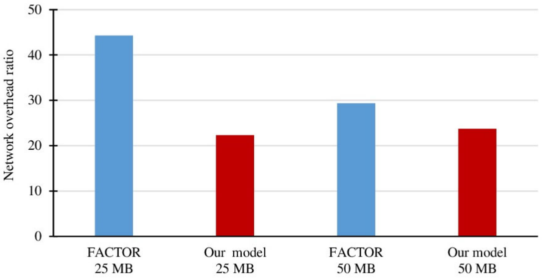

Fig. 5 Network overload ratio as a function of buffer size for 25 vehicles.

This figure shows that both systems reduce network overhead more for the 50 MB capacity buffer than the 25 MB capacity buffer. However, compared to Factor, our model reduces the network overhead better. Indeed, the network overhead ratio of our model ranges from 22.30 to 23.72 for the 25 MB and 50 MB capacity buffers respectively. In contrast, in the case of Factor, the overhead ratio varies from 44.29 for 25 MB to 29.37 for 50 MB. This reduction in network overhead in our model is due to the fact that in this model, replications are reduced by using the message weighting function.

Evaluation of delivery ratio for 50 vehicles

By analogy to the previous cases, for each of the 30 simulation batches we determine the average message delivery ratio by priority class for 50 vehicles. These results of average message delivery ratio by priority class for 50 vehicles with the 25 MB and 50 MB capacity buffer are collected in Table 4.

Table 4: Average delivery ratio by priority class of our model and Factor for 50 buffer vehicles of 25 and 50 MB capacity.

Priority class	Buffer management systems	25 MB	50 MB
Low priority	Factor	7,47	18,17
	Our Model	51,52	48,57
Medium priority	Factor	13,46	43,83
	Our Model	58,36	57,40
High priority	Factor	67,64	72,31
	Our Model	71,19	78,83

Fig. 6 shows the delivery ratio of high priority, medium priority and low priority messages when the buffer size varies from 25MB to 50MB for our model and that of Factor when the network contains 50 vehicles.

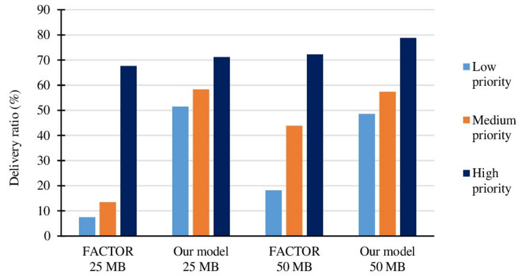

Fig. 6 Message delivery ratio by priority class as a function of buffer size for 50 Vehicles.

For this figure, there is confirmation of the previous results. Indeed, our model allows us to obtain significantly higher delivery ratio of messages by priority class (48.6% and 79%) than those of Factor (7.5% and 72%).

However, regarding our model, there is a small reduction in delivery ratio for low and medium priority messages when the buffer size varies from 25 MB to 50 MB. Indeed, for low priority messages, there is a reduction in the delivery ratio of 5% (ratio between 51.52% and 48.57%). For medium priority messages, the reduction in delivery ratio is 1.6% (ratio between 58.36% and 57.4%).

Evaluation of the network overload for 50 vehicles

By analogy to the previous section, we determine the average network overload ratio using the 30 simulation batches. These results of the average network overload ratio for 50 vehicles with buffer capacity of 25 MB and 50 MB are collected in Table 5.

Table 5: Average network overload ratio of our model and Factor for 50 vehicles of 25 MB and 50 MB buffer capacity.

	Buffer management systems	25MB	50 MB
Network overload ratio	Factor	153,57	111,36
	Our Model	76,18	88,15

Fig. 7 shows the impact of buffer size on the network overhead ratio for our model and Factor when the network consists of 50 vehicles.

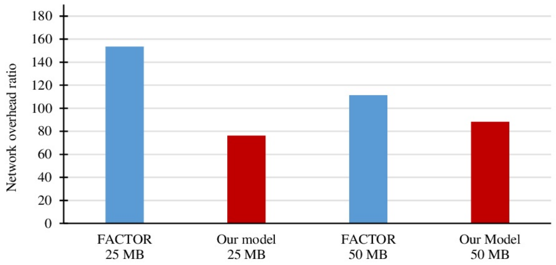

Fig. 5 Network overload ratio as a function of buffer size for 50 vehicles.

Fig. 7 shows a quasi-similarity with Figure 5, we can deduce that compared to Factor, our model reduces the network overhead more. Indeed, our model based on the message weight allows to reduce the replications and consequently the resource consumption than Factor.

Conclusion of the evaluations when the buffer varies from 25 MB to 50 MB

This study shows that our model performs well compared to Factor. Indeed, when the buffer capacity varies from 25MB to 50 MB, for a given number of vehicles, our model improves the delivery ratio per priority class and reduces the network overhead better than Factor. However, this performance is more noticeable when the buffer capacity is 50MB.

As mentioned above, in the next section, we set the vehicle buffer capacity to 50MB and vary the number of vehicles in the network.

Results of the variation in the number of vehicles from 25 to 150

Evaluation of delivery ratio by priority class

By analogy to the previous section, for each of the simulation batches, we determine the average message delivery ratio (AMDR) by priority class. These results of the average message delivery ratio by priority class for our model and that of Factor when the number of vehicles varies from 25, 50, 100 and 150 are collected in Table 6.

Table 6: Average delivery ratio by priority class for our model and Factor when the number of vehicles varies.

number of vehicles	**Buffer management systems**	**Low priority**	**Medium priority**	**High priority**
25 Vehicles	Factor	22,33	49,48	61,09
	Our Model	41,97	51,99	64,51
50 vehicles	Factor	18,17	43,83	72,31
	Our Model	48,57	57,40	78,83
100 vehicles	Factor	9,19	16,01	77,77
	Our Model	64,56	64,14	85,26
150 vehicles	Factor	7,28	10,77	88,21
	Our Model	80,36	80,21	92,00

Evaluation of delivery ratio for low and medium priority messages

To compare the performance of our model against Factor, for each number of vehicles, we determine the difference between the delivery ratio (DBDR) by priority class of our model and those of Factor. The results are shown in Table 7.

Table 7: Difference in delivery ratio of low and medium priority messages from our model and Factor as a function of the number of vehicles.

number of vehicles	**Buffer management systems**	**DBDR of Low priority (%)**	**DBDR of Medium priority (%)**
25 Vehicles	Factor	19,65	2,52
	Our Model		
50 vehicles	Factor	30,41	13,58
	Our Model		
100 vehicles	Factor	55,38	48,12
	Our Model		
150 vehicles	Factor	73,08	69,44
	Our Model		

Fig. 8 and Fig. 9 show the impact of the number of vehicles on the delivery ratio of our model and Factor for low and medium priority messages respectively.

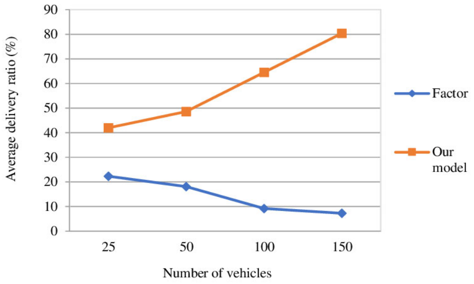

Fig. 8 Average delivery ratio of low priority messages by number of vehicles.

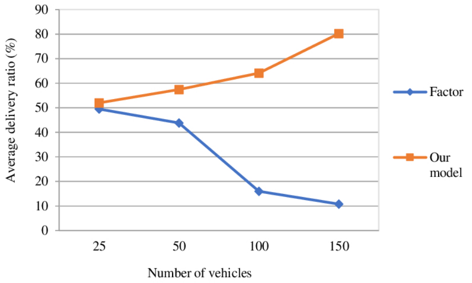

Fig. 9 Average delivery ratio of medium priority messages by number of vehicles.

Fig. 8 and Fig. 9 show that for an increase in the number of vehicles (from 25 vehicles to 150 vehicles), we observe a large increase in the delivery ratio of low and medium priority messages in the case of our model compared to Factor. Moreover, taking into account the differences in the delivery ratio of low priority messages (19.65% to 73.08%) and medium priority messages (2.62% to 69.44%) between our model and Factor, we can state that the performance in terms of delivery of low and medium priority messages is held by our model.

Evaluation of High Priority Message Delivery Ratio

In this section, we compare the performance in terms of improving the delivery ratio of high-priority messages of our model against those of Factor, for a given number of vehicles. As a result, we determine the difference between the average delivery ratio of the high priority messages in our model and those in Factor on the one hand and the standard deviations of the 30 simulation batches of the delivery ratio of the high priority messages on the other. These results are shown in Table 8.

Table 8: Evaluation of the delivery ratio of the high priority messages of our model and of Factor as a function of the number of vehicles.

number of vehicles	**Buffer management systems**	**Average delivery ratio (%)**	**Difference (%)**	**Standard deviation**
25 vehicles	Factor	61,09	3,42	1,78
	Our Model	64,51		1,68
50 vehicles	Factor	72,31	6,51	2,40
	Our Model	78,83		1,15
100 vehicles	Factor	77,77	7,49	3,45
	Our Model	85,26		0,71
150 vehicles	Factor	88,21	3,79	1,26
	Our Model	92,00		0,71

Fig. 10 shows the impact of the number of vehicles on the delivery ratio of high priority messages in our model and in Factor.

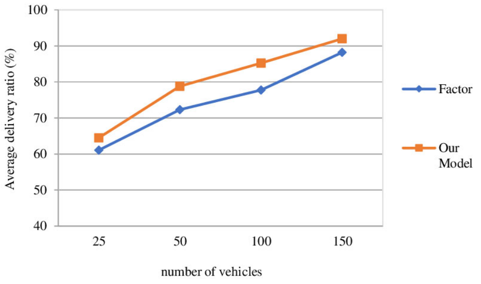

Fig. 10 Average delivery ratio of high priority messages by number of vehicles.

In contrast to Fig. 8 and 9, Fig. 10 shows an increase in the high-priority message delivery ratio of our model and Factor when the number of vehicles varies from 25 vehicles to 150 vehicles.

However, comparing the differences in high priority message delivery ratio between our model and Factor shows the good performance of our model compared to Factor. Indeed, these differences are 3.42%, 6.51%, 7.49% and 3.79% when the number of vehicles is 25, 50, 100 and 150 respectively. Moreover, the calculations of the standard deviations obtained from the different simulation batches confirm this result. Indeed, when the number of vehicles varies from 25 to 150, the standard deviations of the delivery ratio of high priority messages of our model (1.68; 1.15; 0.71; 0.71) are lower than those of Factor (1.78; 2.4; 3.45; 1.26).

These results also show that the Factor policy is only effective for delivering high priority messages.

Evaluation of the average delivery delay of high priority messages

In order to evaluate the performance of our model in terms of reducing the average delivery delay of high priority messages compared to Factor, we determine for each of the simulation batches the average delivery delay of high priority messages.

Then, we compute the differences between the average delivery delay of the high-priority messages of our model and those of Factor on the one hand and on the other hand the standard deviations of the simulation batches of the delivery ratio of the high-priority messages. The results are shown in Table 9.

Table 9: Evaluation of the average delivery delay of the high priority messages of our model and Factor as a function of the number of vehicles.

number of vehicles	**Buffer management systems**	**average delivery delay (min)**	**Difference (%)**	**Standard deviation**
25 vehicles	Factor	65,27	0,03	1,43
	Our Model	65,30		1,38
50 vehicles	Factor	63,14	-1,98	1,34
	Our Model	61,17		1,19
100 vehicles	Factor	55,70	-2,38	0,86
	Our Model	53,32		0,77
150 vehicles	Factor	45,21	-2,78	0,79
	Our Model	42,44		0,72

Fig. 11 shows the impact of the number of vehicles on the delivery delay of high priority messages in our model and Factor.

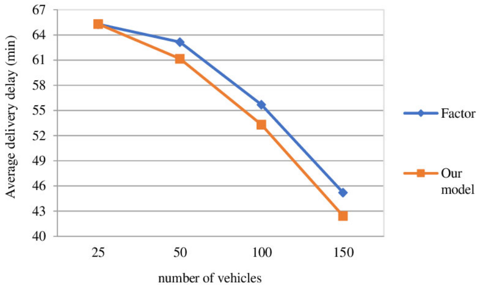

Fig. 11 Average delivery delay for high priority messages as a function of the number of vehicles.

This figure shows that the average delivery delay for high priority messages decrease with both models when the number of vehicles varies from 25 to 150 vehicles. However, the reduction in average delivery delay is more noticeable with our model than with Factor.

Indeed, the comparison of the differences in the average delivery delay of high priority messages between our model and Factor varies from 0.03 min to -2.78 min when the number of vehicles varies from 25 to 150. Moreover, the calculations of standard deviations confirm these results. Indeed, when the number of vehicles varies from 25 to 150, the standard deviations of the delivery delay of high priority messages of our model (1.38; 1.19; 0.77; 0.73) are lower than those of Factor (1.43; 1.34; 0.86; 0.79).

Evaluation of network overload

In this section, we compare the network overload reduction performance of our model to that of Factor, for a given number of vehicles. Therefore, for each of the simulation batches, we determine the average network overload ratio. Then, we calculate the difference between the average overload ratio of our model and those of Factor. The results are shown in Table 10.

Table 10: Evaluation of the network overload ratio of our model and Factor as a function of the number of vehicles.

number of vehicles	**Buffer management systems**	**Average network overload ratio**	**Difference**
25 vehicles	Factor	29,37	-5,64
	Our Model	23,72	
50 vehicles	Factor	111,36	-23,21
	Our Model	88,15	
100 vehicles	Factor	452,29	-207,34
	Our Model	244,95	
150 vehicles	Factor	977,98	-599,07
	Our Model	378,91	

Fig. 12 shows the impact of the number of vehicles on network overload ratio for our model and Factor policy when the number of vehicles varies from 25 to 150.

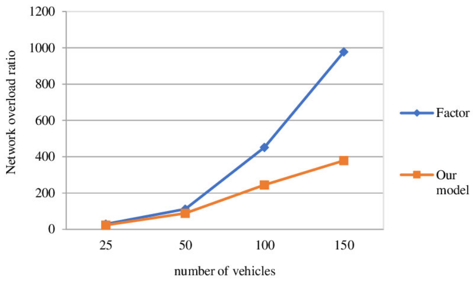

Fig. 12 Network overload ratio as a function of the number of vehicles.

Fig. 12 shows that our model reduces the network overload better than Factor when the number of vehicles varies from 25 to 150 vehicles. Furthermore, the comparison of the network overload ratio differences between our model and Factor which ranges from -5.064 to -599.07 shows the good performance of our model in terms of network overload reduction compared to Factor.

This reduction in network overhead by our model is due to the fact that in this model, the weight expression is a function of parameters such as the number of copies, and the number of hops. Therefore, the old messages in the buffer that have the high copy and hop counts are preferentially deleted. This significantly reduces the resource consumption.

4. Conclusion

In this paper, we have proposed a new buffer management strategy based on the message weight. This memory management strategy consists of a message drop policy and a buffer message scheduling policy. The drop policy is based on the nature of the current node, the position of the intermediate node with respect to the destination, and the distribution of messages into two queues, one of which is made up of recent messages and the other of old messages. Thus, it allows the oldest message to be removed from the buffer. The scheduling policy is based on the selection of the most recent message from the high-weight queue of recent messages and the priority class.

The results of simulations performed with the ONE simulator, show that compared to Factor which guarantees the transfer of high priority messages, our model reduces the network overhead significantly, reduces the delivery delay of high priority messages and improves the delivery ratio of messages of all priority classes in a low and high node density environment. Therefore, our model is more suitable for improving traffic safety.

In perspective, we propose a new approach to improve road safety. Indeed, this paper is based on a V2V communication architecture because of the high cost of road communication infrastructures [20] on the one hand and on the other hand on the unicast performance of the PRoPHET routing protocol [15]. Since the presence of these infrastructures contributes to the improvement of road safety, we need to propose a new approach that will reduce the number of traffic accidents while minimizing the number of roadside equipment to be installed. In addition, a multicast communication solution must be implemented to cover a large geographical area.

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