# Selection of Retransmitter Nodes for Alert Message Transmission in VANETs Using a Multicriteria Decision-Making Approach Based on Vehicle Credibility

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Abstract: Adverse situations that occur on public traffic roads, such as traffic accidents, severe traffic jams, among others, are considered critical traffic events. Such events occur relatively frequently and need to be dealt with quickly by public authorities to maintain the proper functioning of cities and highways. The main challenges for efficient handling lie in the random nature of the event and the speed and accuracy of its notification to the authorities. Thus, the large number of vehicles on the roads, together with their communication and monitoring capabilities, allow the detection and alert of such events occurrences. However, transmitting such detections to the destinations can be difficult due to the not entirely reliable nature of those involved, especially when there is a need for retransmission of the alert message between the detecting vehicle and the destination. In this sense, choosing the most suitable etransmitter vehicle, among the possible ones, becomes an issue. In this sense, this work proposes the development and use of a Vehicle Credibility Factor (VCF) in Ad Hoc Vehicular Networks (VANETs), generated by means of the use of several criteria that represent traffic behavior, as input parameters for the AHP multicriteria decision-making method. The result of the method is the VCF, which is used to determine, by ranking, the most reliable vehicles to transmit sensitive information for alerting critical traffic events.



## 1 INTRODUCTION

Mobility, especially in large cities and highways, has become increasingly difficult due to the high number of vehicles on the roads (Damjanović et al., 2022). As a result, various traffic accidents, congestion, construction, and other events occur daily, leading to road closures or potential risks to the lives of drivers and pedestrians. Therefore, these events need to be communicated quickly and securely to the authorities involved in traffic management and other road users so that well-informed decisions can be made to handle these events. Thus, technological solutions are necessary to detect and communicate these events. One such solution is the spontaneous formation of communication networks among vehicles traveling on these roads. These networks are known as Vehicular Ad Hoc Networks (VANETs).

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VANETs represent mobile networks where communications facilitate the exchange of information between vehicles and road infrastructures, proving to be a promising solution for monitoring and alerting about critical traffic events that influence users' routes and travel times. To this end, the use of vehicle clustering (Andrade et al., 2020), V2V (vehicle-to-vehicle) and V2I (vehicle-to-infrastructure) communication strategies are identified as effective solutions (Tomar et al., 2010).

Given the structure and large number of vehicles in a VANET, information must be transmitted smoothly and efficiently. Therefore, it is necessary to find a way for participating vehicles to act as transmitters and retransmitters to disseminate all stored data and events that occur. However, retransmission is not always necessary, such as in cases where the vehicle detecting the event can send the message directly to the final destination. In situations where direct communication is not feasible, the message must be retransmitted by another vehicle.



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Therefore, the credibility of the vehicles involved can determine whether the message about a critical event reaches its destination. In other words, selecting credible vehicles to retransmit the message can be crucial for the message to be retransmitted. Thus, the assessment of credibility, through a calculation that considers various factors, for each vehicle within these networks must be accurately computed to find the most suitable vehicle in the information transmission chain for the communication of these events.

In this way, this work proposes a method for selecting retransmitter vehicles for alert messages regarding critical traffic events in VANETs based on the credibility of the involved vehicles. To accomplish this, it introduces the implementation and calculation of a new Vehicle Credibility Factor (VCF) in a VANET. This work incorporates new criteria for modeling credibility and utilizes the Analytical Hierarchy Process (AHP) method for decision-making.

In this context, this work seeks to answer the research question regarding how the VCF influences the selection of retransmitter vehicles in simulations of VANETs and what impacts are observed on the efficiency of communication and the network. Therefore, the main objective of this work is to develop and validate a method that uses the VCF, calculated using various criteria, to select the most efficient vehicles for disseminating crucial information within vehicular networks.

Thus, the remainder of this work is structured as follows. Section 2 discusses related works. Section 3 describes the proposed vehicle credibility factor based on credibility criteria, and its use along with the AHP method to compute a score for each vehicle involved in the retransmission of the alert message. Section 4 presents the scenario where the proposal was simulated in a VANET considering real mobility data from the city of Luxembourg. Finally, Section 5 concludes the work and presents suggestions for future improvements.

## 2 RELATED WORK

This section discusses some related works on the topic of efficient and reliable vehicle selection in a VANET.

The work (Tomar et al., 2010) addresses the dissemination of information in VANETs. It proposes the use of information collection units along the roads and the formation of vehicle clusters, as this approach achieves low latency in information transmission with grouped vehicles and also expands the connectivity of the VANET. However, a limitation of this work is the dependency on the information collection units, which may lead to single points of failure and network overload. The proposed approach aims to address this by using a more distributed and resilient system for data collection and dissemination.

The work (Andrade et al., 2020) discusses MINUET, a system for detecting and disseminating urban events in VANETs. MINUET enables monitoring and distribution of these events through the creation of cooperative vehicle clusters that communicate with each other. With the simulation results presented, it was demonstrated that MINUET ensures greater information availability and is capable of sending more monitoring data packets. However, the system may face scalability issues and network congestion in scenarios with high vehicle density. The approach adopted in this work, although primarily focused on the efficient selection of retransmitter vehicles, may indirectly improve communication efficiency by reducing the number of retransmitters needed to transmit an alert message, potentially enhancing communication in denser scenarios regarding network congestion issues.

The work (Yury et al., 2020) presents SOCIABLE, a system for disseminating critical urban events in a Social Internet of Vehicles environment. Using vehicle communications based on social criteria, information about critical events is distributed to external entities. The article compared the performance of SOCIABLE with MINUET (Andrade et al., 2020). Thus, SOCIABLE has shown to transmit fewer packets and achieve significantly lower delays compared to other event dissemination systems. However, a disadvantage of SOCIABLE is that it may not guarantee complete coverage of the area in certain scenarios, due to its reliance on social criteria, which are not always uniformly distributed. The proposal of this work addresses this issue by introducing new criteria, such as behavioral factors (related to vehicle credibility), which seek a more consistent and comprehensive alert message dissemination, potentially resulting in greater efficiency, even in scenarios of high mobility and density.

Thus, the approach proposed in this work seeks to provide an alternative that can solve some of the problems observed in related works. While the focus is on selecting retransmitter vehicles, the proposal aims to contribute to a system that attempts to be more efficient in the selection and communication of vehicles in a VANET. To achieve this, the selection of retransmitter vehicles is based on a combination of criteria such as distance and speed, among other behavioral and technical factors.

## 3 MODELING THE VCF

For the development of the retransmitter vehicle selection method in VANETs, this work assumes that vehicles are equipped with elements (e.g., cameras, sensors, etc.) that, in an integrated and automatic manner, detect such events and inform them through messages sent via the VANET.

When a vehicle detects a critical traffic event and is outside the transmission range of a roadside unit (RSU), it must send the message to a specific vehicle designated to retransmit it. This retransmission process continues from one vehicle to another until the message reaches its final destination. Therefore, in these cases, for the delivery of critical event messages, it is necessary to define a retransmitter vehicle(s), i.e., vehicle(s) that act as intermediate transmitter(s) of the messages if the transmission range of the event-detecting vehicle does not reach the base station or the vehicle that is intended to be reached. The better this retransmitter is chosen, the better the transmission performance of the message will be. Hence, the VCF aims to model the selection of this vehicle as accurately as possible based on all credibility circumstances present during its transit.

The VCF is introduced in this work, establishing several criteria for modeling and consequently calculating the VCF.

The Equation 1 defines the term average speed ($AS$) of the VCF. It is obtained by means of the weighted average of the speed value at which the current vehicle traveled on highways and urban roads.

$$
\begin{aligned}
S_h &= \begin{cases} 1.00 & \text{if } 60 \leq A_h < 110 \\ 0.25 & \text{if } 110 \leq A_h < 150 \\ 0.00 & \text{otherwise} \end{cases} \\
S_r &= \begin{cases} 1.00 & \text{if } 15 \leq A_r < 40 \\ 0.75 & \text{if } 40 \leq A_r < 60 \\ 0.25 & \text{if } 60 \leq A_r < 80 \\ 0.00 & \text{otherwise} \end{cases} \\
AS &= \frac{S_h * n + S_r * m}{n+m}
\end{aligned} \tag{1}
$$

In Equation 1, the weighted average value of the average speeds of the vehicle in $km/h$ is defined by the average speed on highways $S_h$ and on urban roads $S_r$, to which a value between 0 and 1 is assigned based on the speed at which the current vehicle traveled on highways $Ah$ and on urban roads $A_r$. $n$ and $m$ refer to the monitored hours while the vehicle traveled on highways and urban roads, respectively.

Equation 2 represents the peak hour traffic term ($PH$) that results from the amount of hours traveled during a defined time interval in the simulation.

$$PH = \left(1 - \frac{h_d}{t_t}\right) * w_d + \left(1 - \frac{h_n}{t_t}\right) * w_n \tag{2}$$

In Equation 2, the calculation of $PH$ is given by the time traveled during peak daytime hours $h_d$ and nighttime hours $h_n$ in relation to the total time traveled $t_t$ over a month, weighted by $w_d$ (day) and $w_n$ (night). During the simulation conducted in this article, the weight values were selected as $w_d = 0.25$ and $w_n = 0.75$, so the less time traveled during peak nighttime hours, the better the final value of the criterion $PH$ will be.

Equation 3 defines the term ($DT$) representing the total driving time of the driver, where $t_t$ is the variable that stores the total driving time of the driver in hours over a month.

$$DT = \begin{cases} 1.00 & \text{if } t_t \leq 30 \\ 0.75 & \text{if } 30 < t_t \leq 60 \\ 0.50 & \text{if } 60 < t_t \leq 150 \\ 0.25 & \text{if } t_t > 150 \end{cases} \tag{3}$$

Equation 4 defines the term ($KM$) for the total distance driven by the driver, where $km$ is the variable that stores the total distance driven by the driver over a month.

$$KM = \begin{cases} 1.00 & \text{if } km \leq 1000 \\ 0.75 & \text{if } 1000 < km \leq 2000 \\ 0.50 & \text{if } 2000 < km \leq 3000 \\ 0.25 & \text{if } km > 3000 \end{cases} \tag{4}$$

Equation 5 defines the term ($LD$) for the total licensed time of the driver, where $ld$ is the variable that stores the total time the driver has been licensed in years.

$$LD = \begin{cases} 1.00 & \text{if } ld > 10 \\ 0.75 & \text{if } 5 < ld \leq 10 \\ 0.50 & \text{if } 2 < ld \leq 5 \\ 0.25 & \text{if } 1 < ld \leq 2 \\ 0.00 & \text{if } ld \leq 1 \end{cases} \tag{5}$$

Equation 6 defines the term ($F$), reflecting the driver's behavior in terms of traffic violations committed.

$$F = \left[ \left(1 - \frac{p}{p_{max}}\right)^{\frac{m}{m_{max}}} \right] * \left(1 - \frac{m_m}{lm_{max}}\right) \tag{6}$$

In Equation 6, $F$ is the final value assigned to the criterion, $p$ represents the score of the fines attributed to the vehicle, $p_{max}$ represents the maximum score of fines within the monitored group of vehicles, $m$ is the number of fines of the analyzed vehicle, $m_{max}$ is the maximum number of fines of a vehicle analyzed within the group of vehicles, $m_m$ is the number of months the analyzed vehicle was fined over a year, and $lm_{max}$ is the maximum period that the current legislation stores the fines of a given vehicle.

Equation 7 represents the term $(YV)$ related to the year of manufacture of the vehicle. Thus, the age of the vehicle $a_v$ is calculated by the difference between the year of manufacture $a_m$ and the current year $a_a$. Finally, the final value of the criterion is assigned based on the current age of the vehicle.

$$a_v = a_m - a_a$$
$$YV = \begin{cases} 1.00 & \text{if } a_v \leq 10 \\ 0.75 & \text{if } 10 < a_v \leq 20 \\ 0.50 & \text{if } 20 < a_v \leq 40 \\ 0.25 & \text{if } a_v > 40 \end{cases} \quad (7)$$

Table 1 represents a parameterized value between 0 and 1 within the FCV, which takes into account the vehicle's power and the driver's age group for light vehicles. The first column represents the vehicle's power ranges, and the remaining columns represent the age groups. Thus, this value is used as a safety measure, where vehicles with lower power are considered safer to drive and receive high scores for most ages, while higher power vehicles receive higher values for more experienced drivers.

Table 2 is also parameterized between 0 and 1, but it does not take into account power and only considers age groups to drive heavy vehicles.

The criterion $(CS)$, represented by Equation 8, evaluates the average speed of the vehicles' cluster for the VCF. It is obtained through V2V communication and Intelligent Infrastructure if available.

$$CS = \begin{cases} 1, & \text{if } A_v = A_c \text{ or } (A_v \geq A_c \text{ and } A_v < A_c * 2) \\ 0,5, & \text{if } A_v \geq \frac{A_c}{2} \text{ and } A_v < A_c \\ 0, & \text{otherwise} \end{cases} \quad (8)$$

In Equation 8, the value $CS$ is assigned by comparing the average speed of the cluster with that of the current vehicle. Thus, $A_c$ is the average speed of the vehicle cluster and $A_v$ is the average speed of the current vehicle.

Equation 9 defines the tire quality term $(TQ_i)$. It results from an external factor that refers to the current level of wear on each tire.

$$TQ_i = \begin{cases} 1, & \text{if } P \geq 1.6 \quad \text{and} \quad P \leq 3.0, \\ 0.75, & \text{if } P > 3.0 \quad \text{and} \quad P \leq 4.0, \\ 0, & \text{if } P < 1.6 \quad \text{or} \quad P > 4.0. \end{cases} \quad (9)$$

In Equation 9, the value $TQ_i$ depends on the tread depth $P$, which represents the wear of a tire. A relative weight is assigned to the criterion based on the variation in tread depth.

To evaluate the quality of the tires of the vehicle as a whole, which may vary in the number of tires depending on the type of vehicle (such as motorcycles, cars, or trucks), it is established in Equation 10 that the final $TQ$ of the vehicle will be defined as the lowest $TQ_i$ value among all the tires.

$$TQ = \min(TQ_1, TQ_2, \ldots, TQ_n) \quad (10)$$

Thus, the final $TQ$ used for calculating the VCF utilizes an assessment of the overall quality of a vehicle's set of tires based on the tire in the worst condition.

Equation 11 defines the fuel efficiency term $(FE)$ of the VCF.

$$FE = \begin{cases} 1, & \text{if efficiency is A,} \\ 0.8, & \text{if efficiency is B,} \\ 0.7, & \text{if efficiency is C,} \\ 0.4, & \text{if efficiency is D,} \\ 0.2, & \text{if efficiency is E.} \end{cases} \quad (11)$$

In Equation 11, the value $FE$ is defined based on the category of the vehicle's energy efficiency label, which includes values A, B, C, D, and E. These values are extracted from the table of the Brazilian Vehicle Labeling Program (PBEV) (INMETRO, 2024), where the energy efficiencies of many vehicles sold in Brazil are stored and compared. Generally, vehicles that fall into category A are equipped with more advanced technologies, including being more fuel-efficient, which allows them to function more effectively as retransmitters, as they can theoretically travel on roads longer without needing to stop for refueling. As a result, they receive higher scores in this criterion.

The term $D$ of the VCF, representing the distance from the vehicle to the base station, is extracted from the simulation.

The criterion for the number of nearby neighbors of the vehicle, $N$, is extracted from the current node during the simulation. This indicates whether the vehicle is in an area with more neighbors around it, which increases the likelihood that the monitoring message will be transmitted and reach the base station.

Given the complexity of VANETs and the diversity of factors influencing their operations, the selection of the ideal retransmitter vehicle involves analyzing multiple criteria. To address this multiplicity of factors, the use of multi-criteria decision-making methods, such as the AHP, is justified.

Table 1: Relationship between driver age and vehicle power for light vehicles.

| Age Groups | Power (hp) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 60-100 | 110-120 | 130-140 | 150 | 160-170 | 180 | 190 | 200 | 225 | 250-300 |
| 18-29 | 1 | 0.75 | 0.75 | 0.75 | 0.5 | 0.5 | 0.25 | 0.25 | 0 | 0 |
| 30-39 | 1 | 1 | 1 | 1 | 1 | 0.75 | 0.75 | 0.75 | 0.75 | 0.5 |
| 40-49 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0.75 |
| 50-59 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0.75 | 0.75 | 0.75 |
| 60-69 | 0.75 | 0.75 | 0.75 | 0.75 | 0.5 | 0.5 | 0.5 | 0.5 | 0.25 | 0.25 |
| 70-79 | 0.75 | 0.75 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.25 | 0 | 0 |
| 80+ | 0.25 | 0.25 | 0.25 | 0.25 | 0 | 0 | 0 | 0 | 0 | 0 |

Table 2: Driver age and corresponding scores for heavy vehicles.

| Age | Score | Age | Score |
|---|---|---|---|
| 18-29 | 0.75 | 65-66 | 0.5 |
| 30-49 | 1 | 67-69 | 0.25 |
| 50-59 | 1 | 70+ | 0 |
| 60-64 | 0.75 | | |

The AHP is a widely used tool for multi-criteria decision-making, highly effective for solving problems involving different criteria and alternatives (different solutions to the problem). AHP decomposes and divides the problem into various factors that facilitate the establishment of relationships to synthesize the problem (Taherdoost, 2017), making it easier to compare and prioritize the elements.

Thus, all these criteria have their respective weights assigned using the judgment matrix established through the AHP, where criteria are compared pairwise using a scale from 1 to 9, as proposed by Saaty (1991), as implemented and shown in Table 3.

The values from the paired analysis of the criteria, as presented in Table 3, are empirical and take into account the consistency and evaluation of importance among the criteria. The paired analysis results in the weights of each criterion used by the AHP method for scoring each alternative solution being evaluated (in this case, vehicles), allowing for an optimized and well-founded choice.

Each vehicle within the VANET has the criteria previously mentioned. However, not all vehicles in the VANET will be associated (near or within range) with the occurrence of a critical event. Therefore, clustering vehicles is a reasonable approach to optimizing the selection of vehicles that will retransmit the critical event alert message, as clustering techniques can allow efficient communication (Mukhtaruzzaman and Atiquzzaman, 2020) in an organized way, which helps in spreading information throughout the network, enhancing traffic flow, and improving road safety (Zhang et al., 2023). Through clustering, vehicles can swiftly share information within groups about traffic updates, road hazards, or accident alerts, enabling drivers to make quick decisions to avoid traffic jams and collisions.

Thus, the retransmitter is chosen from those that can effectively receive the message and retransmit it in the appropriate direction toward the intended destination. In this regard, by using the SOCIABLE module for the clustering method, vehicles are also grouped based on social criteria (Yury et al., 2020). Among these social criteria, SOCIABLE considers common interests between vehicles, meaning those that have similar destinations, relative speeds close to other vehicles, similar trajectories, and other aspects.

## 4 EXPERIMENT AND RESULT

The evaluation of the retransmitter vehicle selection method for alerts regarding critical traffic events, based on the vehicle credibility factor, was conducted through simulation.

To implement the VCF as well as the proposed retransmitter vehicle selection method, the C++ programming language was used.

In the simulation, a scenario was designed using the NS3 network simulator, an open-source tool widely used in research on ad hoc networks. NS3 allowed for a detailed simulation of the designed scenario, providing a realistic environment for the study.

Additionally, other fundamental systems were integrated into the simulation. Monitoring and Dissemination of Urban Events (MINUET) system was used, which is capable of detecting and efficiently monitoring urban events (Andrade et al., 2020). Furthermore, SOCIABLE system was also employed, which is a critical urban event data dissemination system used for vehicle clustering during the simulations (Yury et al., 2020).

The Simulation of Urban MObility (SUMO) (Krajzewicz et al., 2012) and data from the Luxembourg SUMO Traffic (LuST) (Codecá et al., 2017) were also utilized, modeling urban mobility in the city of Luxembourg and providing a detailed scenario for analysis. In this context, a small route in the city of Luxem-

Table 3: AHP Judgment Matrix.

| # | $N$ | $D$ | $AS$ | $PH$ | $DT$ | $KM$ | $LD$ | $F$ | $YV$ | $AP$ | $CS$ | $TQ$ | $FE$ | **Weights** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $N$ | 1 | $\frac{1}{7}$ | $\frac{1}{5}$ | 1 | 5 | 5 | 3 | $\frac{1}{3}$ | 3 | $\frac{1}{3}$ | $\frac{1}{5}$ | $\frac{1}{3}$ | 5 | 0.046 |
| $D$ | 7 | 1 | 1 | 5 | 9 | 9 | 9 | 2 | 9 | 5 | 1 | 1 | 9 | 0.161 |
| $AS$ | 5 | 1 | 1 | 3 | 5 | 5 | 7 | 1 | 7 | 3 | 1 | $\frac{1}{3}$ | 7 | 0.120 |
| $PH$ | 1 | $\frac{1}{5}$ | $\frac{1}{5}$ | 1 | 2 | 3 | 5 | $\frac{1}{3}$ | 3 | 1 | $\frac{1}{5}$ | $\frac{1}{5}$ | 7 | 0.113 |
| $DT$ | $\frac{1}{5}$ | $\frac{1}{9}$ | $\frac{1}{5}$ | $\frac{1}{2}$ | 1 | $\frac{1}{3}$ | 1 | $\frac{1}{5}$ | 3 | $\frac{1}{3}$ | $\frac{1}{3}$ | $\frac{1}{3}$ | 5 | 0.044 |
| $KM$ | $\frac{1}{5}$ | $\frac{1}{9}$ | $\frac{1}{5}$ | $\frac{1}{3}$ | 3 | 1 | 3 | $\frac{1}{5}$ | 3 | $\frac{1}{3}$ | $\frac{1}{5}$ | $\frac{1}{3}$ | 3 | 0.027 |
| $LD$ | $\frac{1}{3}$ | $\frac{1}{9}$ | $\frac{1}{7}$ | $\frac{1}{5}$ | 1 | $\frac{1}{3}$ | 1 | $\frac{1}{3}$ | $\frac{1}{3}$ | $\frac{1}{5}$ | $\frac{1}{9}$ | $\frac{1}{7}$ | 1 | 0.029 |
| $F$ | 3 | $\frac{1}{2}$ | 1 | 3 | 5 | 5 | 3 | 1 | 7 | 3 | $\frac{1}{3}$ | 1 | 5 | 0.014 |
| $YV$ | $\frac{1}{3}$ | $\frac{1}{9}$ | $\frac{1}{7}$ | $\frac{1}{3}$ | $\frac{1}{3}$ | $\frac{1}{3}$ | 3 | $\frac{1}{7}$ | 1 | $\frac{1}{3}$ | $\frac{1}{9}$ | $\frac{1}{3}$ | 3 | 0.091 |
| $AP$ | 3 | $\frac{1}{5}$ | $\frac{1}{3}$ | 1 | 3 | 3 | 5 | $\frac{1}{3}$ | 3 | 1 | $\frac{1}{3}$ | $\frac{1}{5}$ | 5 | 0.019 |
| $CS$ | 5 | 1 | 1 | 5 | 3 | 5 | 9 | 3 | 9 | 3 | 1 | 3 | 9 | 0.051 |
| $TQ$ | 3 | 1 | 3 | 5 | 3 | 3 | 7 | 1 | 3 | 5 | $\frac{1}{3}$ | 1 | 7 | 0.156 |
| $FE$ | $\frac{1}{5}$ | $\frac{1}{9}$ | $\frac{1}{7}$ | $\frac{1}{7}$ | $\frac{1}{5}$ | $\frac{1}{3}$ | 1 | $\frac{1}{5}$ | $\frac{1}{3}$ | $\frac{1}{5}$ | $\frac{1}{9}$ | $\frac{1}{7}$ | 1 | 0.117 |

bourg was selected, along with 10 vehicles to perform the simulation along this route.

The necessary files for the simulation, such as TraceConfig, TraceMobility, and TraceActivity, were extracted from the geographic coordinates specified in Table 4, providing the foundation for the configuration and execution of the simulated scenario. The data $X$, $Y$, $X_{min}$, and $Y_{min}$ represent the longitude and latitude limits of the geographic area coordinates for the scenario.

Table 4: Coordinates of the Simulation Scenario.

| **Axis** | **Coordinates** |
|---|---|
| X | 6069.44 |
| Y | 4379.33 |
| $X_{\text{min}}$ | 5568.87 |
| $Y_{\text{min}}$ | 3467.69 |

Thus, 10 nodes (vehicles) were defined with a start time of 0.0 seconds and an end time of 700.0 seconds, totaling 11.6 minutes of simulation. The *basestation* (RSU in the simulation) was positioned at the X,Y coordinates of the LuST map representing the simulated scenario, as shown in Table 5, enabling the observation of the proximity criterion with the *basestation*. A fixed critical traffic event was positioned at the X,Y coordinates with the duration specified in Table 6.

Table 5: Coordinates of the Basestation.

| **Axis** | **Coordinates** |
|---|---|
| X | 6020.30 |
| Y | 4390.08 |

Table 7, derived from the simulation of the VANET network operation in NS3, presents the normalized criterion values for the 10 vehicles involved in the simulation, as well as the values for each vehicle's criteria. Thus, it is possible to observe vehicles/-drivers that score lower on some criteria, while others comply more with traffic laws, are closer to ideal conditions. This allows for a visualization of the applicability of the VCF for each vehicle and comparison among the vehicles, assisting in the more accurate selection of the next retransmitter vehicle.

Table 6: Event Settings.

| **Axis** | **Coordinates** | **Start (s)** | **Duration (s)** |
|---|---|---|---|
| X | 5947.46 | 90 | 600 |
| Y | 3948.65 | | |

According to Table 7, it is possible to visualize how, in the simulated scenario, the values of the criteria directly affect the final value of the VCF. Thus, each of these factors significantly affects the choice of the new retransmitter, as it can be observed that vehicles with the lowest final VCF results are those that have the largest number of criteria with lower values. In the simulated scenario, vehicle number 0 would be the current retransmitter in simulation, as it has a higher VCF than the other vehicles.

During simulation, the number of times each vehicle retransmitted critical event alert messages was also collected, as shown in Figure 1. This figure displays the volume of messages retransmitted by vehicles in the simulated scenario. The analysis of the data allows us to observe that different vehicles had different numbers of retransmissions, indicating variations in their roles as retransmitters. Ultimately, these values help in understanding the dynamics of message retransmission during the simulated time period, as well as the evolution conditions (e.g., speed and distance) of the cluster of vehicles involved in retransmitting these messages.

In the conducted simulation, vehicle 6 retransmitted the most alert messages, as it was selected as the

Table 7: Example of VCF Calculation.

| Vehicles | Criteria | | | | | | | | | | | | | VCF |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | N | D | AS | PH | DT | KM | LD | F | YV | AP | CS | TQ | FE | |
| V0 | 0.04 | 0.06 | 1.00 | 0.88 | 1.00 | 0.75 | 0.50 | 1.00 | 1.00 | 0.75 | 1.00 | 1.00 | 1.00 | 0.742 |
| V1 | 0.05 | 0.06 | 0.00 | 0.84 | 0.75 | 0.75 | 0.25 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 0.80 | 0.614 |
| V2 | 0.07 | 0.06 | 1.00 | 0.88 | 1.00 | 0.75 | 0.50 | 1.00 | 1.00 | 0.75 | 0.00 | 1.00 | 1.00 | 0.566 |
| V3 | 0.05 | 0.06 | 1.00 | 0.80 | 0.75 | 0.50 | 0.75 | 0.91 | 1.00 | 1.00 | 1.00 | 0.75 | 0.20 | 0.687 |
| V4 | 0.03 | 0.06 | 0.00 | 0.61 | 1.00 | 1.00 | 1.00 | 0.91 | 1.00 | 1.00 | 1.00 | 1.00 | 0.40 | 0.615 |
| V5 | 0.06 | 0.06 | 0.00 | 0.69 | 0.75 | 0.75 | 0.75 | 0.89 | 1.00 | 1.00 | 1.00 | 1.00 | 0.80 | 0.603 |
| V6 | 0.05 | 0.06 | 0.00 | 0.71 | 0.75 | 0.75 | 1.00 | 0.91 | 1.00 | 1.00 | 1.00 | 1.00 | 0.70 | 0.609 |
| V7 | 0.03 | 0.06 | 0.00 | 0.80 | 1.00 | 0.75 | 1.00 | 0.82 | 1.00 | 0.75 | 1.00 | 1.00 | 0.20 | 0.590 |
| V8 | 0.08 | 0.06 | 0.00 | 0.70 | 0.50 | 0.50 | 1.00 | 0.82 | 1.00 | 1.00 | 1.00 | 0.75 | 1.00 | 0.555 |
| V9 | 0.05 | 0.06 | 1.00 | 0.87 | 1.00 | 1.00 | 0.25 | 1.00 | 1.00 | 0.75 | 1.00 | 0.75 | 0.70 | 0.708 |

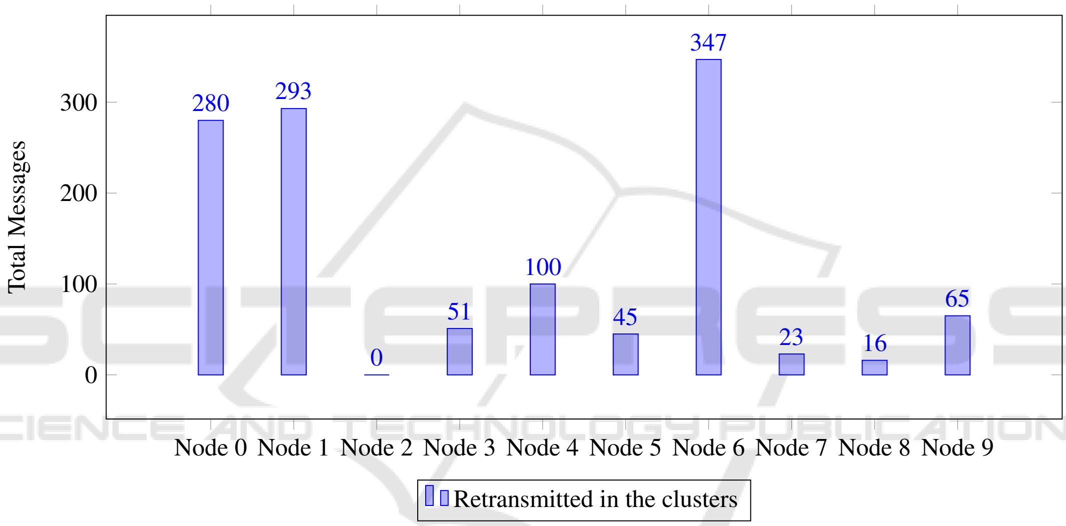


Figure 1: Message Monitoring.



retransmitter more frequently than the others. This was due to its good overall criteria values. On the other hand, vehicle 2 did not retransmit any messages, as it did not achieve favorable VCF values to be selected as a retransmitter. Thus, this demonstrates the influence of vehicle credibility factors on the calculation of the VCF and their impacts on the choice of the retransmitting vehicle.

## 5 FINAL CONSIDERATIONS

This work presented an approach for selecting vehicles to retransmit alert messages regarding critical traffic events. This approach assumes that once a vehicle detects a critical traffic event, it must disseminate an alert message both to other vehicles and to the traffic management infrastructure (such as base stations in the context of an Internet of Vehicles service). Furthermore, it also assumes that this message may need to be retransmitted by another vehicle if direct delivery to the final destination is not possible.

In this context, the proposed approach selects the retransmitting vehicle based on the concept of vehicular credibility, according to a modeling involving various criteria that represent the behavior of the vehicle/driver in urban and road traffic on a daily basis.

To achieve this, a vehicular credibility factor (VCF) is proposed that takes into account various criteria that model such credibility in traffic, using the AHP. The criterion values are utilized by the AHP method to generate the VCF, which acts as a score for the involved vehicles, organized into vehicle clusters during their journey on the transit routes. Thus, the vehicle with the best score in the group (highest VCF) is chosen as the retransmitter, repeating the procedure until the alert message reaches its final destination.

Simulations with real vehicle data organized in a VANET, using the proposed approach for selecting retransmitting vehicles, were conducted. During the evaluation of the VANET scenario simulation, the impact of the proposed criteria on the behavior of each vehicle and the choice of the final retransmitter was clearly observed. The detailed analysis revealed how each criterion directly influences the decision regarding which vehicle should act as the retransmitter, highlighting the effectiveness of the VCF in ensuring the most suitable and efficient choice. Through the simulation, it became evident that the collection of criteria allows for a precise selection of the retransmitter, ensuring that the retransmission of critical information is carried out efficiently. Furthermore, the VCF proved to be a decisive factor in improving communication between vehicles, contributing to a more cohesive and responsive network. The VCF's ability to consider multiple relevant aspects and its practical application in the simulation reinforce its importance as an effective tool in managing vehicle networks, demonstrating that its use can potentially enhance the safety and efficiency of communication in complex urban mobility scenarios.

As a continuation of this work, the performance of the VCF can be tested in its entirety, comparing it with other forms of retransmitter selection. There is also the intention to incorporate additional criteria that address other factors related to vehicular credibility.

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