# Fast and Efficient Vehicle-to-Vehicle Message Dissemination Protocol under Mobility

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***Abstract*—Vehicular ad hoc networks (VANETs) are one of the core parts of an intelligent transportation system (ITS). Upon emergency circumstances, such as accidents or other dangerous situations, VANETs should be able to convey emergency messages to vehicles in potential danger. Since emergency information needs to be transmitted quickly to every vehicle, from one within one hop to one further away, multi-hop broadcasting could be a promising method. Therefore, we propose a Vehicle-aware adaptive Trickle (VaaT) algorithm. The algorithm aims to propagate an emergency message rapidly by considering the distance, speed, and direction of vehicles into a Trickle algorithm, one of the most famous broadcasting methods. The performance of VaaT is evaluated with highway scenarios and is compared to a Trickle algorithm via the ns-3 and SUMO simulators. According to the evaluation, the proposed algorithm enables robust and fast transmission of emergency messages to prevent accidents.**

***Index Terms*—Vehicular Ad Hoc Networks (VANETs), Intelligent Transportation System (ITS), Multi-hop broadcasting**

## I. INTRODUCTION

An intelligent transportation system (ITS) is crucial in modern transportation environments. It aims to offer various advanced services to vehicles and drivers. For example, optimizing traffic flow or forestalling accidents are enabled by ITS based on real-time traffic information. However, to achieve this, the information should be shared with various devices related to ITS. Thus, vehicular ad hoc networks (VANETs) are essential parts of ITS as a foundation for transmitting traffic information for intelligent decisions between vehicles or between vehicles and infrastructure. Notably, VANETs are responsible for rapidly sending emergency messages to vehicles in wide areas to ensure people's safety in emergencies like auto accidents. Therefore, a rapid and efficient transmission mechanism is needed to spread emergency packets to prevent additional accidents.

VANETs can generally consider two transmission types to spread emergency information: unicasting and broadcasting. Particularly, broadcasting is a promising approach because its powerful dissemination performance allows emergency packets to diffuse into neighbors quickly. However, the scenarios of VANETs can be a challenge to broadcasting methods. For example, the mobility of vehicles and various traffic conditions leads to highly dynamic topologies. Therefore, existing broadcasting methods [1]–[3] could not be suitable to VANETs.

For broadcasting in VANETs, several works [4]–[7] are proposed. For example, Wisitpongphan *et al.* [4] proposed p-persistent methods utilizing GPS information or received signal strength. Liu *et al.* [5] introduced an algorithm that integrates cluster-based multi-hop broadcasting using vehicle movement direction with a stochastic transmission technique based on the number of received messages. Luo *et al.* [6] proposed a method to control forwarding nodes by calculating real-time broadcast probability with table information and providing a random delay to increase transmission reliability. Additionally, Baiocchi *et al.* [7] provided a timer-based broadcasting method using the distance information of the sending node to reduce the transmission of spurious messages. However, it is still a difficult problem to broadcast efficiently and robustly in VANETs because nodes have highly dynamic mobility and traffic conditions could be greatly varied.

In this paper, we aim to explore the potential of a Trickle algorithm [8], which is one of the most famous multi-hop broadcasting methods in wireless sensor networks (WSN). To transplant the Trickle's mechanism to VANETs successfully, we propose a Vehicle-aware adaptive Trickle (VaaT). Specifically, VaaT adopts the adaptive transmission timing policy according to the relative position and velocity of neighbor vehicles into a Trickle algorithm in order to reflect traffic conditions and vehicle mobilities. According to the evaluation, VaaT shows rapid and robust broadcasting performance for emergency packet transmission at VANETs compared to Trickle.

## II. TRICKLE ALGORITHM

In this section, we describe the concept of Trickle. Fig. 1 shows an example of Trickle's transmission mechanism. Trickle has two policy periods: a *listen-only period* and a *transmission period*. In a listen-only period state, Trickle's node does not try to transmit. When its period is changed to a transmission period, the node tries packet transmission at a random point in a transmission period. The length of periods is determined by the interval value $\mathcal{I}_{min}$. Initially, each period

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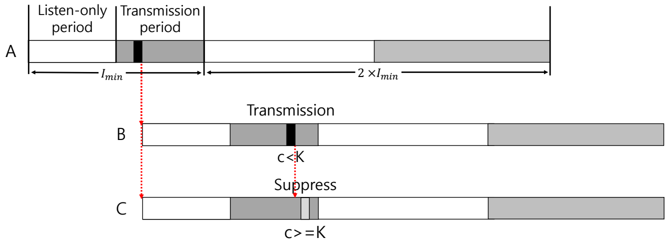


**Fig. 1:** Overview of a Trickle algorithm.

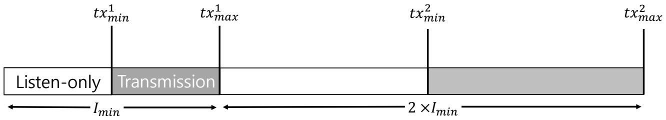


**Fig. 2:** $tx_{min}$ and $tx_{max}$ in transmission periods of Trickle.

length is half of $\mathcal{I}_{min}$. Then, the period length increases twice if Trickle's node tries to transmit the same packet as before. Conversely, if Trickle's node tries to send a new packet, Trickle initializes a listen-only period and a transmission period as half of $\mathcal{I}_{min}$. Specifically, this initialization occurs to a source node when it transmits a new packet according to information changes. On the other hand, it occurs to a relay node when it receives a new packet from neighbor nodes.

Trickle uses a threshold $\mathcal{K}$ and a duplicated packet counter along with the period policy to avoid excessive packet transmission between multiple nodes. For example, in Fig. 1, there are three nodes: $\mathcal{A}$, $\mathcal{B}$, and $\mathcal{C}$. Node $\mathcal{A}$ tries to transmit a new packet, and the other nodes are in the transmission range of not only node $\mathcal{A}$ but also each other. When node $\mathcal{A}$ conducts transmission in its transmission period, node $\mathcal{B}$ and node $\mathcal{C}$ receive the packet and initialize their Trickle intervals because it is a new packet for them. After a listen-only period of node $\mathcal{B}$ and node $\mathcal{C}$, they try to transmit a received packet at a specific point in their transmission period. At this time, if node $\mathcal{B}$ attempts to transmit earlier than $\mathcal{C}$, node $\mathcal{C}$ will receive the same packet already received from node $\mathcal{A}$. In this case, a packet counter of node $\mathcal{C}$ is increased due to receiving a duplicated packet. According to the Trickle algorithm, if a packet counter is more than the threshold $\mathcal{K}$, the node of the counter does not conduct a transmission (**Suppress**). Therefore, node $\mathcal{C}$ suppresses its transmission in the current transmission period. If a node's current period is ended and a new period begins, its packet counter is initialized to 0.

## III. VEHICLE-AWARE ADAPTIVE TRICKLE

Our main scenario in VANETs is to disseminate emergency packets to alert the many vehicles so that they can perceive and avoid potentially dangerous elements. Thus, we aim to spread information rapidly based on broadcasting. For this, our intuition and sight to convey the messages quickly are that the vehicle potentially furthest from the current source location could be more suitable as the next broadcasting node in VANETs. To do this, we modify Trickle's transmission period.

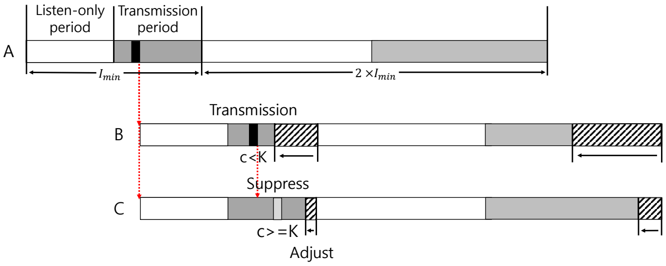


**Fig. 3:** Overview of Vehicle-aware adaptive Trickle (VaaT). VaaT adjusts the transmission period according to distance.

As portrayed by Fig. 2, the transmission period has a specific bound $(tx_{min}, tx_{max})$, and real transmission timing is a value randomly selected from a uniform within the bound. Our approach is to perform broadcasting by adaptively adjusting the bound with the consideration of vehicles' relative location and velocity. Thus, we adjust $tx_{max}$ in a transmission period as follows:

$$tx_{max} = \left(1 - \frac{distance_{pred}}{range_{max} \times \alpha}\right) \times \frac{\mathcal{I}_{min} \times 2^n}{2} \qquad (1)$$

$distance_{pred}$ refers to the expected distance between the sender and receiver vehicles at the start of the next transmission period. For this, it is assumed that each vehicle's position and velocity information is included in the packet. $range_{max}$ is the vehicle's maximum transmission range. $\alpha$ is a variable greater than one and indicates the strength of transmission timing adjustment according to distance. $n$ is the number of intervals (listen-only and transmission periods) for the same packet. Initially, it is 0 and increases by 1 when the node tries to send the packet, the same one as the previous interval, in the current interval.

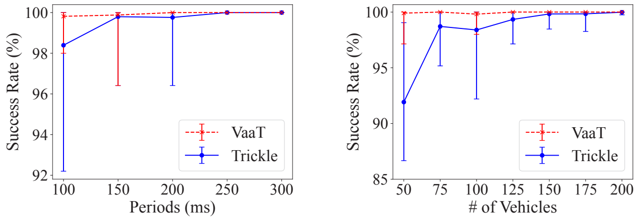
According to Eq. (1), when $distance_{pred}$ approaches the maximum transmission range ($range_{max}$) (i.e., the vehicle's future expected distance increases), $tx_{max}$ approaches $tx_{min}$, as portrayed in Fig. 3. As a result, the random transmission time of distant vehicles approaches $tx_{min}$, and the probability that more distant relay nodes broadcast first increases. For example, in Fig. 3, since the distance at node $\mathcal{B}$ is longer than at $\mathcal{C}$, the $tx_{max}$ value for node $\mathcal{B}$ becomes smaller, increasing the probability of selecting fast transmission time. However, because their $tx_{min}$ is the same, there still remains a possibility that a closer vehicle will broadcast first.

## IV. EVALUATION

We evaluate the proposed algorithm VaaT compared to a Trickle algorithm. Our implementation of VaaT and Trickle uses C++ and the ns-3 simulator [9]. To simulate traffic scenarios, we configure two-lane highway traffic data via SUMO [10]. We simulate a situation where emergency packets are generated by a vehicle in the middle of a highway road, and the simulation detail is specified in Table I.

**TABLE I:** Simulation parameters

| Simulation Parameter | Value |
|---|---|
| Road length | 5000 m |
| Maximum transmission range | 1000 m |
| Data rate | 6 Mbps |
| Emergency packet size | 200 bytes |
| Vehicle's communication range | 300 m |
| Trickle threshold ($\mathcal{K}$) | 3 |
| $\mathcal{I}_{min}$ | 100 ms |



**(a)** according to periods (100 vehicles) **(b)** according to vehicles (100 ms)

**Fig. 4:** Success rate results from 30 simulations per scenario

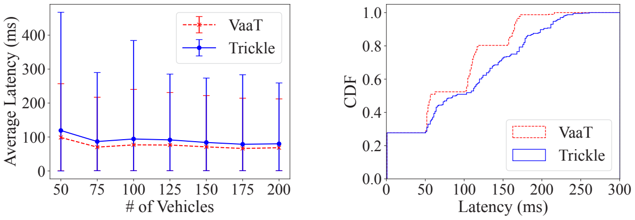
### A. *Success Rate*

We first compare VaaT and Trickle about packet transmission success rate for vehicles within 1000 m from a source node. Fig. 4a presents the success rate results when there are 100 vehicles on the road. A total of five scenarios are simulated according to new emergency traffic generation periods from 100 ms to 300 ms. Both VaaT and Trickle show a 100% transmission success rate over 250 ms, but Trickle failed to achieve a 100% success rate in a 200 ms scenario. Additionally, although VaaT does not achieve 100% in the 100 ms and 150 ms scenarios, it represents a higher success rate than Trickle in both scenarios.

Fig. 4b portrays the transmission success rate when the speed of new emergency traffic occurrence is 100 ms. With the fixed occurrence period, we conduct simulations with seven vehicle scenarios (50 to 200 vehicles). In this simulation, VaaT showed a higher success rate than Trickle in all scenarios. In particular, while Trickle does not achieve a 100% success rate in any scenario, VaaT achieves a 100% transmission success rate in five scenarios.

### B. *Latency*

We also measure the latency results to verify whether VaaT can disseminate emergency information rapidly to prevent potential accidents. Fig. 5a presents average latency results when the new emergency traffic generation period is 300 ms. We configure a total of seven vehicle scenarios (50 to 200 vehicles), and VaaT shows the lower average latency for all scenarios. This means that VaaT shows stronger broadcasting performance than Trickle and that our proposed adaptive policy to consider the characteristics of VANETs is effective. Fig. 5b portrays the CDF of packet latency for one scenario when the number of vehicles is 100 and the traffic generation period is 300 ms. VaaT represents a shorter latency distribution, and the dissemination to all targeted vehicles is finished more quickly than Trickle.



**(a)** Average latency (300 ms) **(b)** CDF (100 vehicles, 300 ms)

**Fig. 5:** Latency results from 30 simulations per scenario

## V. CONCLUSION

This paper aims to disseminate emergency messages rapidly through VANETs to prevent potential accidents. Multi-hop broadcasting is an effective method for disseminating emergency messages, and Trickle is one of the famous broadcasting algorithms. However, Trickle is not designed for VANETs. To enable efficient broadcasting based on Trickle at VANETs, we propose a Vehicle-aware adaptive Trickle (VaaT) algorithm. According to the evaluation, VaaT shows rapid and robust information dissemination in VANETs by considering their characteristics. We believe that this study shows the potential of Trickle-based algorithms in VANETs, and we will further improve Trickle's policy through more advanced traffic situation recognition methods in the future.

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