# VANET-Based Ad-hoc Simulation of Vehicle Trajectories in Accident Scenarios

Tran Anh Kiet,...

January 15, 2024

**Abstract**

This study addresses the challenges of traffic accident analysis in areas where installing cameras or VANET roadside units is hindered by difficult terrain. Recognizing that accidents can occur unpredictably across diverse landscapes, we propose a novel ad hoc data transmission method for simulating the trajectory of vehicles during accidents. This approach leverages the adaptability of ad hoc networks to provide a reliable and efficient means of data collection in the absence of traditional traffic monitoring infrastructure. Our simulation results indicate that this method can effectively reconstruct accident scenarios, thereby offering valuable insights for traffic management and emergency response strategies in challenging environments.

## 1 Acknowledgement

Financial Support: Mentioning grants, scholarships, or other funding sources that made the research possible.

Institutional Support: Acknowledging universities, laboratories, companies, or research centers that provided resources or infrastructure.

Individual Contributions: Thanking colleagues, mentors, peers, or anyone who provided significant academic input, technical assistance, or who read and offered feedback on drafts of the manuscript.

Editorial Support: Sometimes, thanks are given to editors or proofreaders who helped refine the article.

## 2 Introduction

Traffic accidents are an unpredictable and unfortunate reality, occurring across various landscapes and often in places lacking surveillance infrastructure. In remote or complex terrains, where the establishment of traditional traffic monitoring systems like cameras or Vehicle Ad-hoc Networks (VANET) roadside units is unfeasible, there remains a significant gap in accident analysis and response capability. This paper explores the potential of ad hoc data transmission as a solution to this problem.

Ad hoc networks, characterized by their decentralized nature and capability for dynamic self-organization, present a promising alternative to conventional fixed-infrastructure networks. By leveraging the mobility of vehicles and the robustness of ad hoc communication, we propose a method to simulate vehicle trajectories post-accident, offering a deeper understanding of the incident dynamics.

We begin with a comprehensive review of the challenges faced in traffic accident analysis, particularly in areas with hard terrain such as rocky or craggy landscapes. We then detail the methodology for employing ad hoc data transmission to capture and simulate vehicular motion in the absence of direct observation tools. Furthermore, we discuss the development and validation of a simulation model that accurately reflects real-world vehicle behavior during accidents.

The implications of this research are far-reaching, offering not only a methodological advancement in traffic accident analysis but also practical applications for emergency response and traffic management in areas traditionally underserved by technology. By addressing the need for flexible and terrain-agnostic traffic monitoring solutions, this study contributes to the body of knowledge in intelligent transportation systems and emergency preparedness.

For the introduction, I included an expansion on the significance of the study and hinted at the structure of the paper, which is a typical approach in academic writing. This should set the stage for more detailed sections on literature review, methodology, and implications.

## 3 Related Work

The "Related Work" section of an academic article provides an overview of previous research that is directly relevant to the current study. It serves several important purposes:

Contextualization: It situates the current research within the broader field, showing how it fits into and contributes to the existing body of knowledge.

Literature Review: It summarizes past studies, theories, and findings that are pertinent to the research question or problem being addressed.

Highlighting the Gap: It identifies limitations, discrepancies, or gaps in the existing literature that the current research aims to fill or address.

Building a Foundation: It shows the foundation on which the current study is built, including theoretical frameworks, methodologies, and key findings from other researchers.

Avoiding Duplication: It demonstrates the authors' awareness of what has already been done, thus avoiding unnecessary duplication of previous work.

Justifying the Research: It provides a rationale for the current study, explaining why the research is important and needed.

# 4 Background

The "Background" section of an academic article lays the groundwork for understanding the research problem and its significance. It is where the authors provide a broader context for the study, explaining the circumstances or conditions that led to the need for the research. Here's what it typically includes:

Historical Context: An overview of the evolution of the topic or problem over time, which may involve a brief review of key developments or discoveries.

Current Situation: A description of the state of the topic at the time of writing, including recent findings, current debates, or new methodologies.

Theoretical Framework: The theories or concepts that underpin the research. This might include definitions of key terms, explanations of relevant principles, or descriptions of conceptual models.

Problem Statement: A clear articulation of the specific problem or challenge the research is addressing, which is often linked to the gaps identified in the related work section.

Relevance: The importance or implications of the problem for the field, practice, or society. This can include potential applications of the research, its significance for policy, or how it might advance scientific understanding.

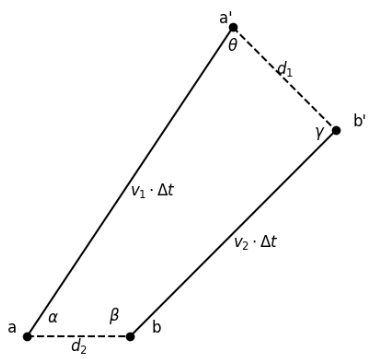
# 5 Methodology

The data that a vehicle sends include:

- $v$ (Velocity of the Vehicle): The current speed at which the vehicle is moving. It can be measured using the vehicle's speedometer, which calculates speed based on wheel rotation.
- $\phi$ (Angle of Movement): This angle represents the direction of the vehicle's movement relative to a fixed reference, such as the direction of the receiving vehicle or a cardinal direction (like North). This can be measured using a compass or a gyroscope sensor in more advanced systems.
- $\delta t$ (Time Elapsed Since Broadcast): The time that has elapsed since the vehicle last broadcasted its message. It indicates the freshness of the information being transmitted.
- $\Delta t$(Broadcast Cycle Time): The regular interval at which a vehicle broadcasts its information packet. A shorter $\Delta t$ means more frequent updates.

## 5.1 Simple model: Interaction between 2 vehicles

### 5.1.1 Theory calculation




The interaction between two vehicles is predominantly based on the continuous exchange of broadcast data. This data includes each vehicle's velocity, the angle of movement, and the frequency of data broadcast. Here, we delve into how this data can be utilized to understand the dynamic relationship and relative motion between two vehicles over time.

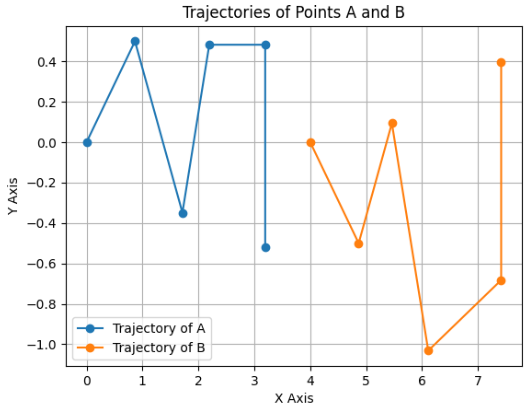
- **Data Utilization:**
  - Each vehicle continuously broadcasts its current velocity $v$ and the angle $\phi$ of its movement.
  - The velocity is measured using the vehicle's speedometer and might be influenced by various factors such as road conditions and traffic.
- **Distance Calculation:**
  - Over a small time interval $\Delta t$, the distance each vehicle travels is calculated as $v \times \Delta t$.
  - For instance, if vehicle 1 has a velocity $v_1$, it travels a distance $v_1 \times \Delta t$ during the interval.
- **Distance Calculation Between Vehicles Using Radio Waves:** Calculating the distance between two vehicles using radio wave propagation offers a novel approach in vehicular networks. This method is based on the time-of-flight principle of radio signals.
  - *Methodology:* The procedure begins by recording the time of the last radio signal broadcast from the transmitting vehicle. Upon receiving this signal, the receiving vehicle notes the current time. The time difference between the current time and the last broadcast time, denoted as $\delta t$, represents the time taken for the radio wave to travel between the two vehicles.
  - *Distance Calculation:* Radio waves travel at the speed of light $c$. Hence, the distance $d$ between the vehicles is calculated using the equation:

    $$d = c \cdot \delta t$$

    This calculation is essential in real-time applications such as collision avoidance systems and adaptive cruise control in intelligent transportation systems.
- **Angle Determination:**
  - The angle between the velocity vector of each vehicle and a reference line (say, the line joining the two vehicles) is crucial.
  - These angles, $\alpha$ for vehicle 1 and $\beta$ for vehicle 2, can be determined using onboard angular sensors or calculated using trigonometric relationships.
- **Trajectory Mapping:**
  - By repeatedly calculating these distances and angles over successive intervals, we can map out the trajectory of each vehicle.
  - This iterative process helps in visualizing the path and understanding the dynamics of each vehicle over time.

### 5.1.2 Simulation

This is a simple simulation of the progress:

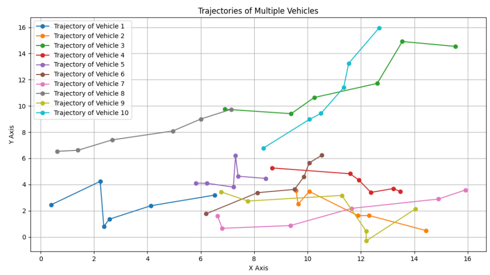



## 5.2 General Model: Interaction Between Multiple Vehicles

In a scenario involving multiple vehicles, each vehicle is assigned a unique identifier (ID). This ID is used to track and record the trajectory data of each vehicle. The trajectory data for each vehicle is stored in a structured format, allowing for comprehensive analysis of their movements. The data structure can be represented as follows:

- **Data Structure for Each Vehicle:**
  - The trajectory data for each vehicle is stored in a structured format: `data[vehicle_ID] = {[X_1, Y_1, time_1], [X_2, Y_2, time_2], [X_3, Y_3, time_3], ...}`.
  - Each entry in this data structure contains the X and Y coordinates of the vehicle at a given time, providing a detailed record of its movement.
- **Trajectory Data Storage:**
  - Each vehicle's trajectory is recorded and indexed by its ID: `trajectory[vehicle_ID] = {data[1], data[2], data[3], ...}`.
  - Here, $data[n]$ represents the set of data record by the $n$th vehicle.
- **Trajectory Analysis and Visualization:**
  - A simple approach to analyze these trajectories is to take the average of the X and Y coordinates at different time intervals.
  - This approach allows for plotting the trajectories of each vehicle, providing a visual representation of their paths and interactions over time.

This model facilitates the analysis of complex interactions between multiple vehicles in a VANET. By systematically storing and processing each vehicle's trajectory data, we can gain insights into traffic patterns, potential collision points, and overall network dynamics.




## 5.3 Data collection and processing

In this section, we will solve several problem, include:

- **Advanced Data Management** Sort the data first by ID, then by time. Implement a method to identify and remove noise from the data. Exclude data for vehicles that are broadcasted from a distance exceeding a certain threshold (e.g., 500 meters).
- **Collision Detection Method** The collision detection method in our vehicle simulation system is designed to accurately and efficiently identify potential collisions between vehicles. This process is critical for assessing risks and implementing safety measures in real-time. The method comprises several key steps and techniques:

  - Check if the time is the same

  - Check if two vehicle is overlap: A simple way to check if two rectangles (representing vehicles) intersect is to compare their edges.If one rectangle is on the left side of the other or above the other, they don't intersect. Otherwise, they intersect.

  - Store that all the accident information

  - We only consider the local data used for simulation the accident, not the whole journey of that vehicle. So we can define when to delete all the unused data.

# 6 Experimental Results and Performance Evaluation

## 6.1 Software Simulation

## 6.2 Hardware Simulation

# 7 Conclusion

Your conclusion text here.

# References