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Technologies used in vehicular networks for effective eco-friendly intelligent transportation system in smart cities

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Abstract: Today, Vehicular Networks (VNs) can significantly improve the safety and sustainable growth of Intelligent Transportation Systems (ITSs) for smart cities. VNs offer efficient solutions to persistent urban problems such as congested roads and roadway safety. VNs adopt a wide range of technologies such as Vehicle-to-Vehicle (V2V), Vehicle-to-Infrastructure (V2I), and Vehicle-to-Everything (V2X) communications. These technologies allow cars to communicate with each other and with road infrastructure such as Roadside Units (RSUs) in real time, as well as enable the sharing of data. This can effectively mitigate accidents, enhance traffic flow, and minimize air pollution. Our paper extensively explores the state-of-the-art VN technologies used to establish safe and sustainable transportation systems. Additionally, our study highlights the importance of connectivity among automobiles for smarter urban environments to enhance transportation and support environmentally friendly growth. This is done by utilizing the Veins simulator in our work for conducting different mobility and traffic simulations. We formulate various scenarios, where we use the vehicles' speed for our performance evaluation. Furthermore, we use OMNeT++ and SUMO for the accurate simulation of traffic motion in the city of Cairo, where results demonstrate that the speed of vehicles employing Vehicular Ad-Hoc Networks (VANETs) communications is not affected by traffic congestion.

Keywords: *Collaborative driving, Intelligent transportation systems (ITSs), Network simulation, Roadway safety, Smart cities, Traffic management, Vehicular ad-hoc networks (VANET), Vehicular networks (VNs).*

1. Introduction

Annually, numerous individuals have injuries or fatalities due to automobile collisions. To mitigate these problems, intelligent automobiles have smart devices, such as sensors, recording devices, and GPS, which can detect nearby objects while offering essential information for safe driving [1]. Such information is exchanged via Vehicular Networks (VNs) with other automobiles or road infrastructure to enhance safety on roadways. The GPS provide accurate location information for safety and non-safety applications, such as location-based services (LBSs) [2].

VNs use specialized communications called Dedicated Short-Range Communication (DSRC) to facilitate communication among vehicles known as Vehicular Ad-Hoc Networks (VANETs) in order to provide safer driving experience [3]. VN uses technologies such as Vehicle-to-Vehicle (V2V), Vehicle-to-Infrastructure (V2I) and Vehicle-to-Everything (V2X) communications [4]. For instance V2V communication enables cars to exchange information on their velocity along with position and direction which may be utilized to prevent accidents and improve collaborative driving. V2I connection enables cars to receive data from traffic lights and various other infrastructure components as well as facilitates variable traffic control and immediate guidance modifications. Thus, VNs have the potential to enhance road safety and minimize air pollution for smart cities [5].

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Contributions of this paper are as follows. First, this paper presents an extensive overview of the state-of-the-art VN technologies used to establish safe and sustainable transportation systems. Also, our study highlights the significance of connectivity among automobiles for smart cities to enhance urban transportation and support eco-friendly ITS.

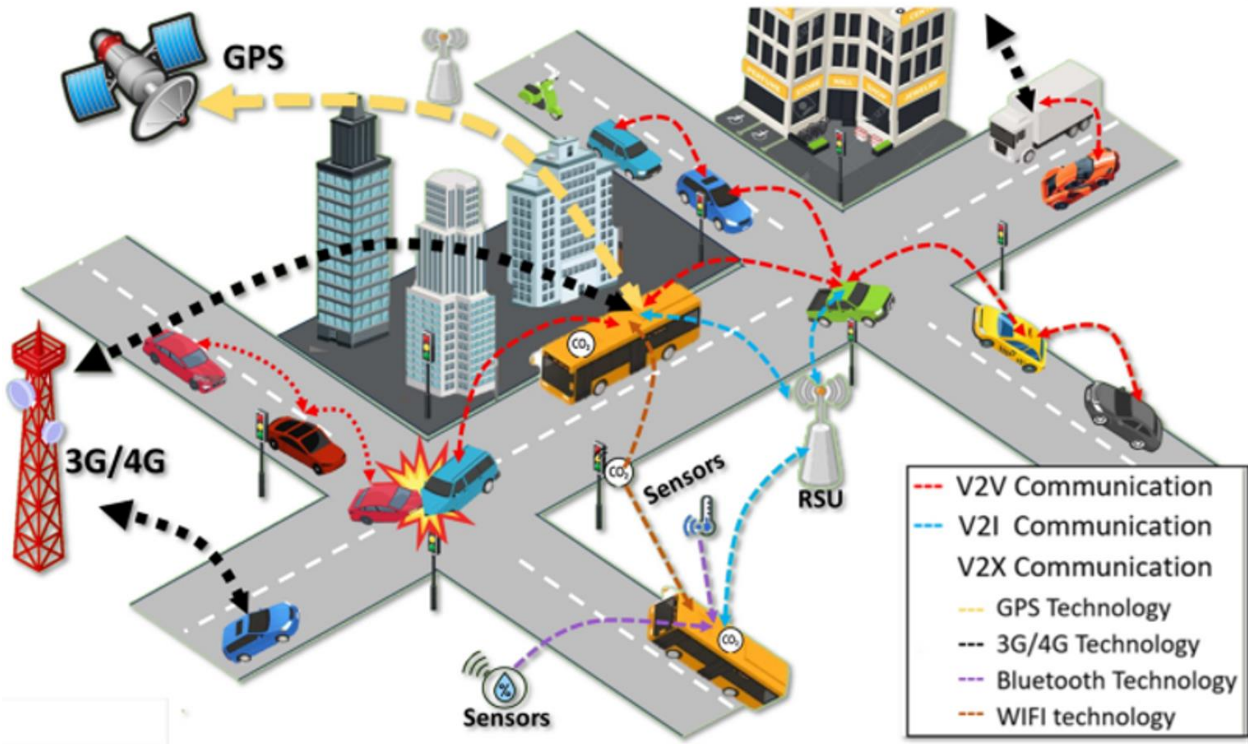

Figure 1.
VN technologies.

Besides that, we adopt the Veins simulator for performing various mobility and traffic simulations. We generate different traffic scenarios, where we use the vehicles' speed for our performance evaluation. In our work, we employ the OMNeT++ and SUMO for the accurate simulation of traffic motion of city of Cairo. Our results show that the speed of vehicles which adopt VANET communications are not affected by traffic congestion.

This paper is divided as follows. First, in Section 2, different technologies used by VNs are presented. Then, various VANET applications are discussed in Section 3. While, the state-of-art VANET communication technologies are explained in Section 4. In Section 5, we provide an overview of VN simulation. Whereas, in Section 6, we demonstrate our simulation results and discuss them. Finally, in Section 7, our conclusion and proposed future work are discussed.

2. VN Technologies

There are many types of technologies used by VNs. For instance, in VANETs, automobiles interact with each other by using ad-hoc network connectivity [6]. When cars exchange data via road infrastructure, this sort of communication is referred to as V2I communication. Currently, Artificial Intelligence (AI) and machine learning (ML) are being incorporated into V2I communication to enhance congestion forecasting and handling of emergencies. While, if the application necessitates a combination of inter-vehicular communications (IVC), the communication is referred to as V2V communication. Figure 1 depicts a smart city where automobiles can communicate through various types of VNs [7].

The implementation of 5G networks is anticipated to improve VANET communications, known as Cellular V2X (C-V2X) through the provision of increased data rates and expanded capacity.

2.1. Roadside Unit

Roadside Units (RSUs) provide the following primary uses: facilitate interaction between vehicles and road facilities (V2I) as well as among themselves. A RSU is an essential element in the foundation of Intelligent Transportation Systems (ITSs) and VANETs. RSUs are fixed devices that are commonly deployed along roadways or at crossroads. Through facilitating V2I connection, RSUs provide direct connection between cars and the power source located alongside the road. Adding to that, RSUs have the capability to gather data on the movement of traffic, the speeds of vehicles, and the degrees of congestion. This data may be utilized for both immediate traffic control and future transportation planning. Smart cities make use of RSUs to assist in directing drivers away from traffic jams [8]. Also, RSUs can serve as mediators to augment the reach of V2V interactions by facilitating the flow of data between automobiles that are not within coverage range. So, RSUs offer real-time data regarding highway circumstances, congestion flow, road hazards, and traffic lights which enhances traffic management and road safety. RSUs provide signalling synchronization for advanced mobility networks which encourages the gradual adoption of ITS applications, such as smart driving technologies and autonomous vehicles [9]. Examples of RSU use cases include the following:

- Traffic Management Centres (TMCs): function as central devices which gather information gathered from RSUs and cars to monitor and control road circumstances through the entire road system. This is to enhance traffic flow and promptly address any accidents that may occur.
- Dynamic Traffic Management (TM): RSUs installed at strategic junctions have the capability to dynamically modify traffic signal timings by utilizing immediate traffic information gathered from cars. This results in a reduction in rush hour traffic, lowering journey durations and enhancement in the overall efficiency of traffic movement [10].
- Handling of incidents: If a collision occurs, RSUs can rapidly distribute data to other cars, notifying them to decrease speed or choose different paths, thereby minimizing likelihood of further accidents.

2.2. V2V Communication

V2V communication refers to exchange of data amongst automobiles allowing them to transmit data, such as their route status. Common sent messages shared by all cars consist of: GPS position, speed, heading of vehicle, vehicle control information (angle of steering wheel, brake status), vehicle tracking history and forecast. Essential components for V2V communications include:

- DSRC: A technological standard for automotive applications that operates at 5.9 GHz band. It enables fast and dependable communication that is crucial for applications that need high levels of safety.
- Basic Safety Messages (BSM): Standard communications that automobiles exchange to provide vital information, such as position and speed of vehicle.
- On-Board Units (OBUs): Embedded devices in cars that have V2V communications features. These devices consist of transceivers and computational processors for telecommunications.
- Antenna systems: Guarantee dependable delivery and acquisition of V2V signals, which are bidirectional to encompass any route surrounding vehicles.

There are many uses of V2V communications Tian, et al. [11] such as:

- Accident prevention: V2V interaction facilitates the exchange of up-to-date data on locations and motions of automobiles, thereby allowing collision avoidance devices to alert motorists regarding possible crashes and implement proactive measures.

- Urgent stop lighting: In the event of unexpected braking, an automobile can transmit a signal to cars behind it notifying them to respond quickly.
- Intersection Movement Assist (IMA): System that aims to prevent crashes at junctions via exchanging information about the paths of vehicles and identifying any conflicts.
- Cooperative Adaptive Cruise Control (CACC): It utilizes V2V communications for effective traffic management by improving the movement of traffic and minimizing traffic jams.
- Automobile monitoring: V2V communication enables the monitoring of suspected cars by transmitting their data to corresponding authorities.
- Improved guidance: V2V connection enables the transmission of up-to-date congestion information resulting in more precise and adaptable route choices.
- Warning of hazardous road conditions: V2V enable cars to interact and exchange information on hazardous roadways including incidents or severe climate. As a result, drivers might receive immediate notifications and adjust their paths accordingly.

2.3. V2I Communication

V2I communication refers to real-time interchange of data between vehicles and roadside infrastructure components, such as traffic lights, road signs, and toll booths. Components of roadside infrastructure also include RSUs that gather data from cars and then broadcast them. IEEE 802.11p is a wireless communication standard which is part of IEEE 802.11, is specifically developed to provide wireless connectivity for automotive applications. DSRC is based on WAVE (Wireless Access in Vehicular Environments) and is the prevalent communication standard for V2V and V2I applications.

V2I is essential for enhancing safety, managing traffic flow on highways, and increasing productivity in smart cities Boehmlaender, et al. [3] some of the advantages of V2I include:

Table 1.
Safety and Non-Safety VANET Applications.

VANET Applications							
Non-Safety				**Safety**			
Comfort		**Traffic Information Systems**		**Situation Awareness**		**Warning Messages**	
Contextual Information	Amusement	Optimal Speed Advisory	Congestion Accident Information	Adaptive Cruise Control	Blind Spot Warning	Traffic Light Violation	Electronic Brake Light

- Safety: V2I communication enables instantaneous data sharing which decreases fatality of accidents through alerting automobiles to possible red-light violations or existence of pedestrians [10]. Also, it enables communication between rescue trucks and traffic lights during emergencies.
- Signal Phase and Timing (SPaT) Information: V2I technology allows cars to receive up-to-date information on the current status and timing of traffic signals, which decreases crossroads accidents. Also, work zone warnings, where RSUs communicate data to automobiles, allowing drivers to get early notifications and receive recommendations for alternate routes to prevent delays and improve safety. Besides that, notifications of potential dangers on the road, where RSUs relay information such as slippery surfaces or obstacles or accidents, so enabling drivers to proactively respond.
- Green Light Optimal Speed Advisory (GLOSA) system: Provides vehicles with speed suggestions to smoothly pass through oncoming traffic signals when they are green which leads to less fuel consumption.
- Electronic Toll Collection (ETC): V2I technology enables automated toll payment which results in reduced delays and improved traffic flow at tolling locations.

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- Parking management: Offers up-to-date data on parking space availability, guiding cars to unoccupied places and minimizing the duration of parking search.
- Environmental monitoring: Equipping RSUs with sensors to monitor pollutants in the air or background noise or other environmental factors.
- Green Transport**:** Promotes eco-friendly practices via minimizing fuel consumption.

2.4. V2X Communication

V2X communication refers to communication of vehicles with other entities such as cyclists, pedestrians, etc. It promotes autonomous driving by supplying vehicles with all necessary data for making optimal choices, such as selecting best route [12]. V2X has the added advantage of integrating several ITS innovations including V2V and V2I connections within a unified system. So, it allows for optimized ITS via decreasing congestion and enhancing road safety.

Moreover, C-V2X is a technology that utilizes cellular networks, LTE and 5G, to enable different types of vehicular communications, such as V2V, V2I, and V2X. It provides faster data transmission speed, and a wider coverage range compared to DSRC [13].

3. VANET Applications

VANETs applications aim to enhance the safety and efficiency of public transit networks [1]. They are classified as safety and non-safety applications as shown in Table 1 [14]. Some of the VANET applications are discussed as follows:

- Emergency Automobile Warning System: Rescue automobiles can connect more quickly with surrounding automobiles while having higher priority than other automobiles, such as ambulances and fire trucks, which allows the way to be freed for them. Also, data can be transmitted immediately to rescue teams during emergencies, such as vehicle accidents. For instance, if a crash occurs, a car might promptly alert a rescue agency by providing information about collision, such as number of passengers. This reduces response times and enhances overall effectiveness of rescue systems.
- Entertainment: Offers accessibility to electronic content including music, films, video games, etc.
- Misbehaviour Detection: This is essential to guarantee dependability and security, since VANETs are susceptible to cyberattacks that might threaten the effectiveness of ITSs [15-17]. Malicious automobiles can trigger transportation in roadways, thus continuous monitoring of nearby vehicles allow the detection of any abnormal behaviour or alterations in data [18].
- Intelligent Message Routing: For example, NetCLEVER, a flexible multimode application for message routing in VNs [19]. It estimates the level of risk by considering the modifications in speed of automobiles in vicinity and the current speed of a certain automobile, then send alert messages accordingly which would increase the highway safety.
- ML Techniques**:** Actively participates in the development of ITS applications by enhancing traffic control and roadway safety [10]. This is done via utilizing existing traffic patterns, such as during rush hours, to generate forecasting information that helps in decision-making process. For example, this may help ITS agency to implement new routes or bridges to enhance the circulation of traffic.

3.1. Vehicular Sensor Networks

VANET makes use of sensor networks known as Vehicular Sensor Networks (VSNs), which are crucial for building a sustainable ITS and offering extensive data capabilities to support smart cities [20]. There are several uses of VSNs, which are as follows:

- Intelligent alert: Using VSNs, the time and location of crash can be disseminated rapidly which allows vehicles to make timely-manner decisions to prevent road congestion. Also, automobile sensors may detect fires or gas leaks, where an automobile can promptly send alerts to the nearest rescue agency for necessary actions.

- Transportation planning and control: By utilizing intelligent automobile detectors and effective data analysis techniques in VSNs, an advanced traffic circulation surveillance and control system may be developed.
- Cognitive solutions: VSNs can gather authentic auditory data, including automobiles' details and roadway conditions as vehicles pass by. This data can then be utilized to determine the fuel and power and consumption at specific areas and daytimes.
- Enhanced driver support systems: This includes a Radar sensor that utilizes radio waves to detect objects nearby a moving automobile. It functions effectively in many environments and is frequently used in variable speed management. Also, there are cameras that capture necessary images used for various applications such as roadway signs and collision notifications.

4. Vanet Communication Technologies

In this section, we explore the communication technologies used by VANETs to allow wireless connectivity between an automobile and other automobiles or road infrastructure, as shown previously in Figure 1, to enhance navigation efficiency and safety [21]. Automobiles are equipped with these communication technologies for information exchange, such as roadway status [22].

4.1. DSRC Communication

DRSC is the predominant technology employed by VANETs, which is a short-range wireless communication technology specifically for use in VANETs [23]. It is utilized in V2V and V2I communications as it offers minimal cost and delay, which is essential for time-sensitive and critical applications. However, it is restricted by limited capacity and distance making it suitable for transmitting basic information, such as safety warnings. DSRC is essential for the advancement of ITS as it enables a wide range of uses that aim to improve roadway safety and reduce congestion in roadways. The uses of DSRC communication involve the following:

- Automated data gathering: DSRC facilitates uninterrupted data collection by cars, hence minimizing the amount of traffic, for example, collecting toll payments at toll booths.
- Human safety**:** DSRC has the capability to establish communication with wearable devices that pedestrians carry. This allows drivers to be alerted of the presence of pedestrians in situations when visibility is poor or when pedestrians are ready to cross the road.

4.2. Wi-Fi Communication

Wi-Fi has facilitated V2V and V2I communications in VANET. It enables communications with low latency and strong connection, while it consumes greater power compared to DSRC [4]. Also, Wi-Fi may be compromised by interference from nearby wireless devices. For Wi-Fi-based V2V communications, automobiles may provide details, such as position and speed, to enhance roadway safety and avoid accidents [24]. While, for Wi-Fi-based V2I communications, automobiles communicate with road infrastructure allowing drivers to get immediate updates on roadway status and path cautions via emergency support equipment.

4.3. Cellular Communication

Cellular communication plays a vital role in ITS applications by improving traffic control and roadway safety using dependable high-capacity connectivity for VANETs [25]. It utilizes the existing cellular networks, such as 5G, to provide V2V and V2I communications that is essential for contemporary ITS [26]. Automobiles equipped with 5G technology can transfer large amounts of data including high resolution data from sensors, which is needed for high information-demanding applications. Cellular networks are scalable, so they can accommodate a growing number of automobiles and road infrastructure components before experiencing substantial deterioration in reliability. Besides that, cellular communications cover greater communication ranges, in contrast to DSRC, so they are appropriate for usage rural areas. They offer greater protection for transmitted messages across long distances. However, they exhibit higher latency, cost and power consumption as compared to DRSC.

Moreover, the upcoming generation of ITS is expected to adopt a combination of DSRC and cellular communication to enhance capacity and decrease latency. Thus, large amounts of information could be transmitted with low latency, while vehicles transit across different locations, which offers robust ITS. Also, V2X communication can utilize 5G technology, C-V2X, for autonomous driving applications that require continuous rapid interactions [12].

4.4. Satellite-Based Communication

Satellite-based communication is crucial for enhancing communication in VANET especially when traditional communication technologies are insufficient. Examples for scenarios where satellite-based communications are of upmost usage include:

- Remote regions: Automobiles in isolated areas with minimal network connectivity might utilize satellite Internet to access services, such as navigational data.
- Worldwide reporting: This allows vehicles to stay connected in isolated or uninhabitable areas, which offers long-distance connectivity and provides safety.
- Global Navigation Satellite System (GNSS): It offers precise positioning, navigation and timing services that could be used for monitoring and control activities across the globe. GPS is the most well-known type of GNSS.

Despite that satellite-based communication provides global access with minimal delay and high availability, it demands higher resource consumption and cost compared to DSRC or cellular communication technologies.

5. VN Simulation

5.1. Veins Simulator Background

The Veins simulator is an open-source platform specifically designed to perform VN simulation that is needed for ITS applications. It utilizes two simulators, OMNeT++ and SUMO, as shown in Figure 2 Last visited [27] that are linked together by TCP connection and Traffic Control Interface (TraCI) protocol, where they can run concurrently [28]. The OMNeT++ is used as a network simulator, while the SUMO (Simulation of Urban Mobility) simulator is used for road traffic simulation. MiXiM toolkit is employed by OMNeT++ for accurately modelling the physical layer by including radio interference, static and moving obstacles in the simulations.

Veins simulates DSRC and WAVE network protocols, also imports accurate maps and roadway conditions from OpenStreetMap. It allows the simulation of complex transportation configurations in roadways by utilizing SUMO's comprehensive modelling settings of urban areas, roadways, highways, and traffic circulations [10]. Veins allows for dynamic re-routing of automobiles as a response to network packets received via V2V and V2I communications [29]. Also, it could be used for real-time simulations of VNs.

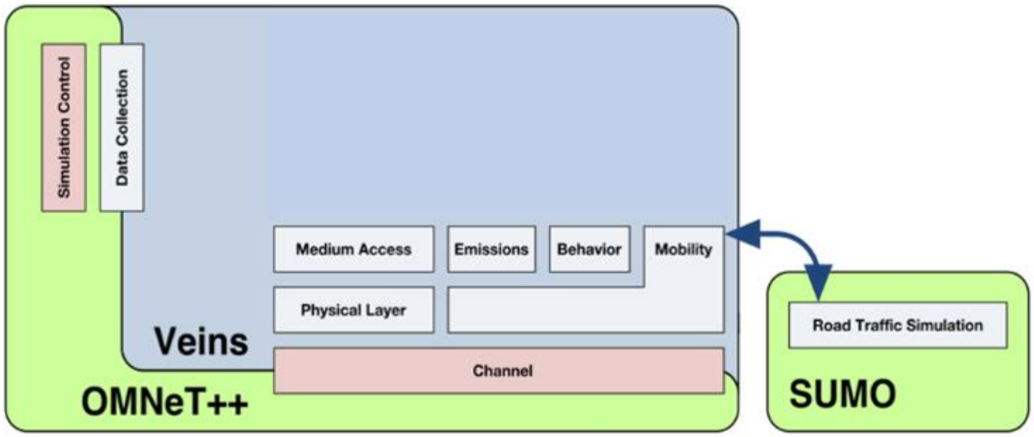

Figure 2.
High-level architecture of Veins.

This assists in transportation planning and infrastructure developments which is beneficial for building sustainable ITS for smart cities.

5.2. Veins Architectural Layout

The Veins is versatile framework that incorporates both SUMO and OMNeT++ simulators for creating and simulating VN communications [27]. This makes it particularly suitable for analysing traffic patterns, congestion and the effects of infrastructural modifications on smart cities. For the OMNeT++, it can analyse various interactions and performance of multiple network elements under diverse settings. It exhibits a modular design that makes it well-suited for combining different mobility models and communication types.

Furthermore, the SUMO considers various parameters such as road infrastructure and mobility models of automobiles for simulating road traffic [21]. SUMO computes real-time information of each automobile, such as current location, direction, and speed. It then sends this information to OMNeT++ to accurately simulate the message transmissions in network. Also, SUMO can accommodate a lot of automobiles as well as model road intersections and roadways of varying sizes, including those present at cities and towns.

5.3. Advantages of Veins

- Veins offers a customized scalable platform for VN simulation which promotes the development of robust ITS in smart cities [18].
- It is utilized to assess the effectiveness of various aspects, such as communication technologies used, autonomous automobiles Mansour, et al. [30] and eco-friendly transport alternatives as it can be used to estimate vehicular emissions.
- It facilitates the creation and evaluation of innovative techniques for automobile navigation that helps in regulating traffic and decreasing congestion.
- Veins includes specialized settings for specific application instances, such as PREXT Emara [31] for location privacy, and Plexe for collaborative driving [27].

6. Simulation and Results

In our simulations, we have modelled different traffic scenarios. In our first scenario, RSUs are used to collect data to detect regions with dense traffic, due to collision, and then transmit alternative routes instructions to automobiles heading to these crowded regions. Consequently, automobiles modify their paths in response to data received, resulting in less traffic congestion and shorter journey durations.

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This showcases capacity of VANET to efficiently handle rush hours in real-time and decrease emissions [32].

Our second scenario demonstrates the capacity of VANETs to grant priority to rescue automobiles, such as ambulances and fire trucks, thus decreasing the response times. The scenario entails a rescue automobile that manoeuvres a congested region. Throughout its motion, the rescue automobile continuously transmits its current location, speed and planned path to neighbouring automobiles and RSUs to clear the way for it. Other automobiles in proximity clear the route for ambulance automobile. This results in enhancing safety and efficiently responding to emergencies.

The third scenario highlights the vital role of VANET in helping to prevent accidents at road intersections and areas with limited visibility.

Figure 3.
RSU receives signals from node 0 via V2I communication.

Our simulation setting models an intersection featuring restricted vision, where several automobiles are coming from different points of view. As automobiles approach the intersection, they share data regarding their current location, speed and planned path. VEINS is used to mimic the motions of cars and possible collision scenarios. Drivers are alerted with warning messages to quickly respond and avoid accidents, leading to higher safety. The simulation showcases the effectiveness of VANET in enhancing safety at intersections.

Finally, our fourth scenario assesses the effectiveness of VANETs in traffic management and energy saving. The situation setting entails a highway, where automobiles form group with other automobiles in proximity. They modify their speed when coming closer to other automobiles to avoid congestion. The simulated scenario demonstrates the capabilities of VANETs in enabling collaboration among automobiles, less fuel consumption and pollution, hence promoting sustainable eco-friendly ITS.

6.1. Veins Simulation

Through utilizing Veins, first we setup a configuration that has several clusters, where each cluster simulate automobiles interconnected via VANET and moving along a roadway. After exactly 50 seconds from start of our simulation run, at a certain point, a collision takes place which causes the automobile involved in accident to stop its motion suddenly. Following the collision, this automobile promptly begins broadcasting warnings to all its adjacent automobile via V2V communications and the nearest RSU via V2I communications to alert them of the occurrence of this incident. As a result of collision, when other automobiles in proximity receive these alerts, they modify their speed and routes to prevent more crashes and traffic jam. In our simulation, the RSU functions as a relay point, which

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broadcasts the received alerts to all moving automobiles in its coverage range. This guarantees that other automobiles are notified and so they will not reach point where collision took place. Instead, other automobiles look for alternative routes, so their total navigation time is not affected by this incident and the overall traffic flow is not affected. In addition to the previously mentioned configuration, we set another one that mimics a rescue automobile that broadcasts messages to all its neighbouring automobiles via V2V communications and the closest RSU via V2I communications to free the route for it.

Figure 3 depicts a comprehensive visual representation that shows a configuration, which consists of a roadway in SUMO and nodes that represents automobiles which are traversing the roadway. The motion and transfer of data signals among automobiles (V2V) as well as between automobiles and RSUs (V2I) are monitored and visualized using OMNeT++ in Figure 3. This configuration demonstrates how RSUs play a major role in broadcasting the signals received, which decreases incident response times thus enhancing the traffic management and roadway safety.

Moreover, Figure 4 presents a V2V communication that takes place after a collision occurred at node 0. As shown in Figure 4, node 0 sends data signals to nodes 1 and 2 informing them about incident happened. Figure 5 shows that, after these nodes received signals from node 0, they change their route and go through alternate routes to avoid moving in same route where crash happened and minimize congestion.

6.2. Real Map Simulation

In this simulation, a real map of Cairo city is imported in Veins from OpenStreetMap. Figure 6 shows the representation of Cairo map exported at 5 pm, a rush hour. In our simulation setup, we used 20 automobiles as shown in Figure 7. OMNeT++ enables accurate simulation of Cairo's traffic flow.

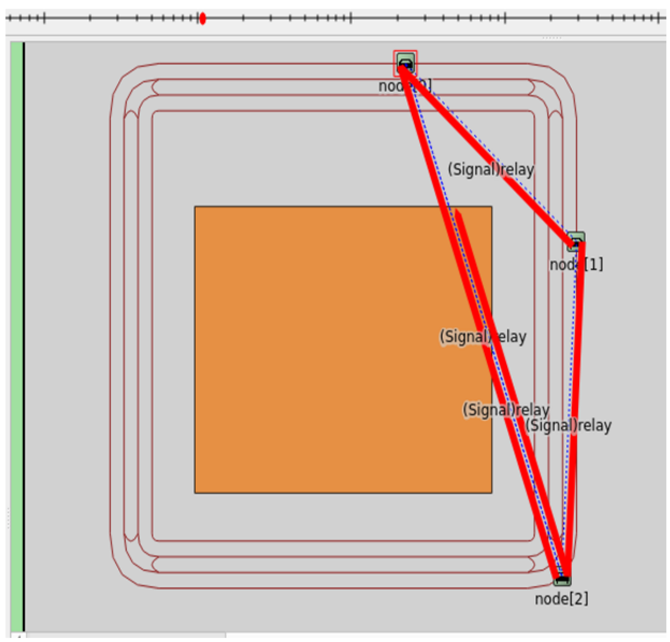

Figure 4.
V2V communication scenario.

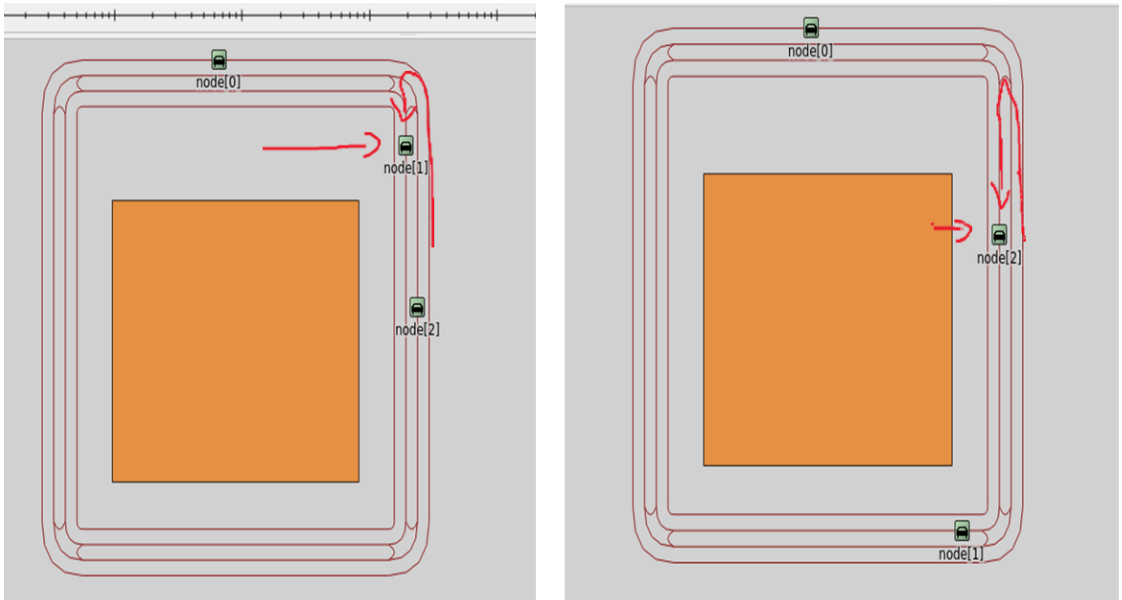

Figure 5.
Nodes 1 and 2 changing their route.

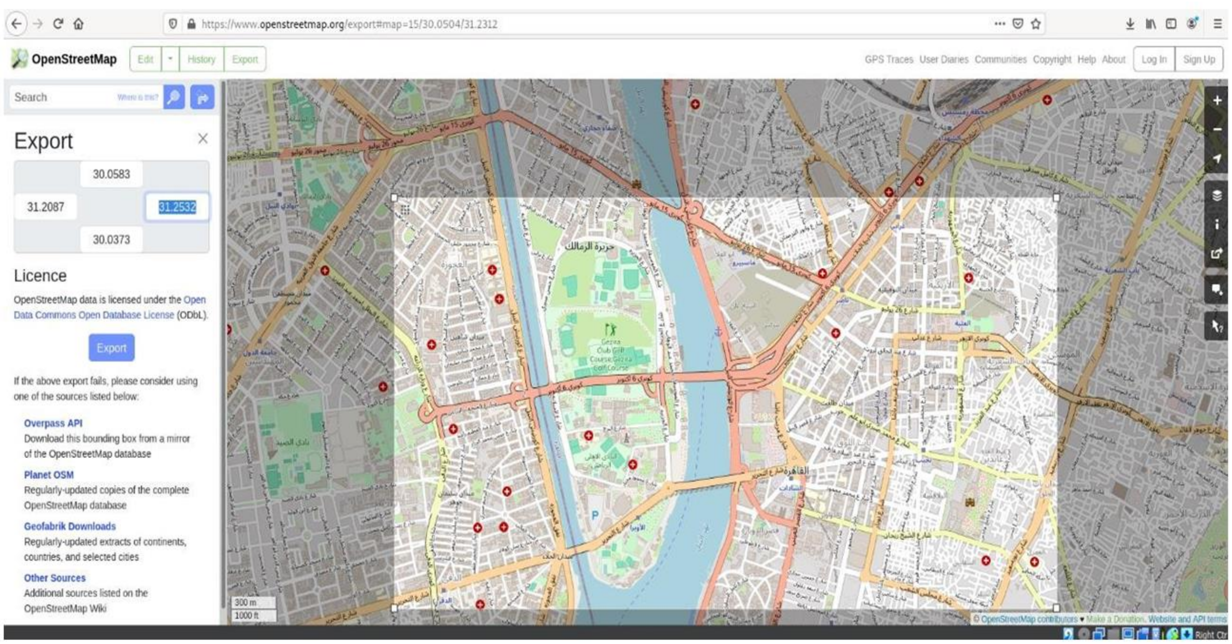

Figure 6.
Cairo static map.

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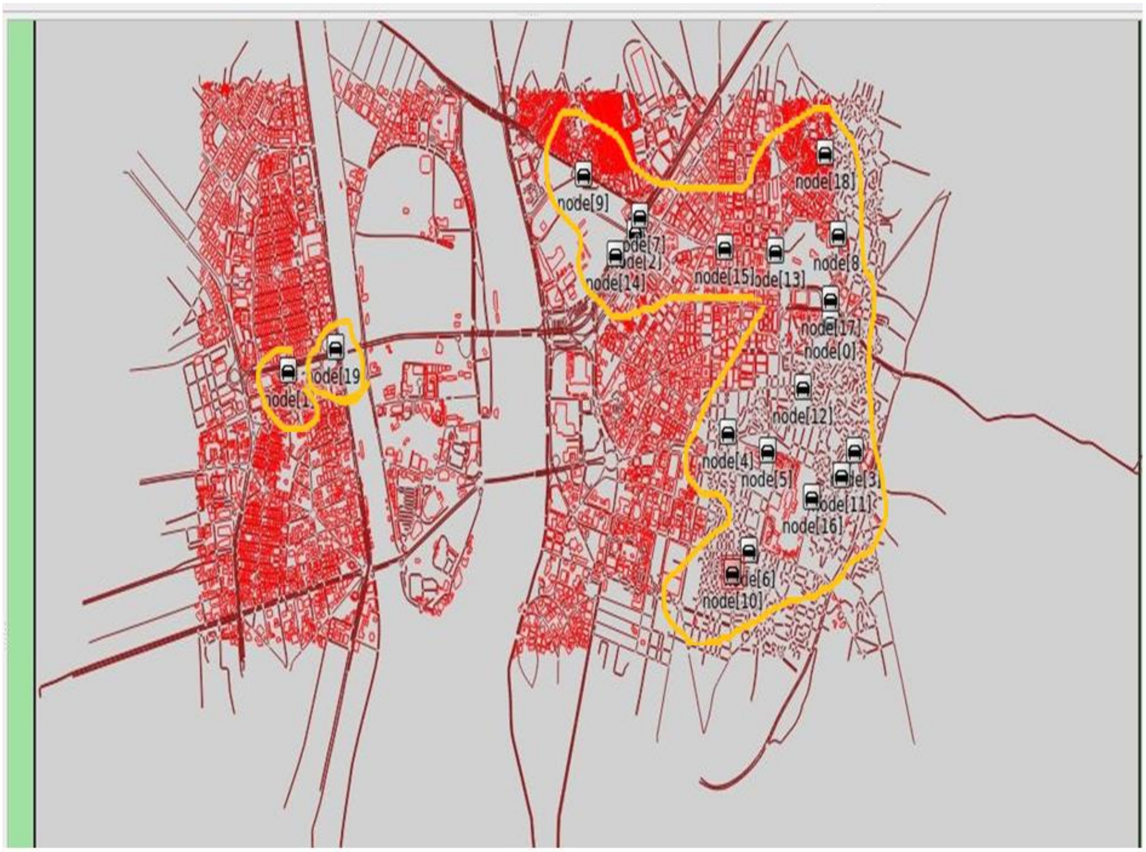

Figure 7.
Cairo's nodes on OMNeT++.

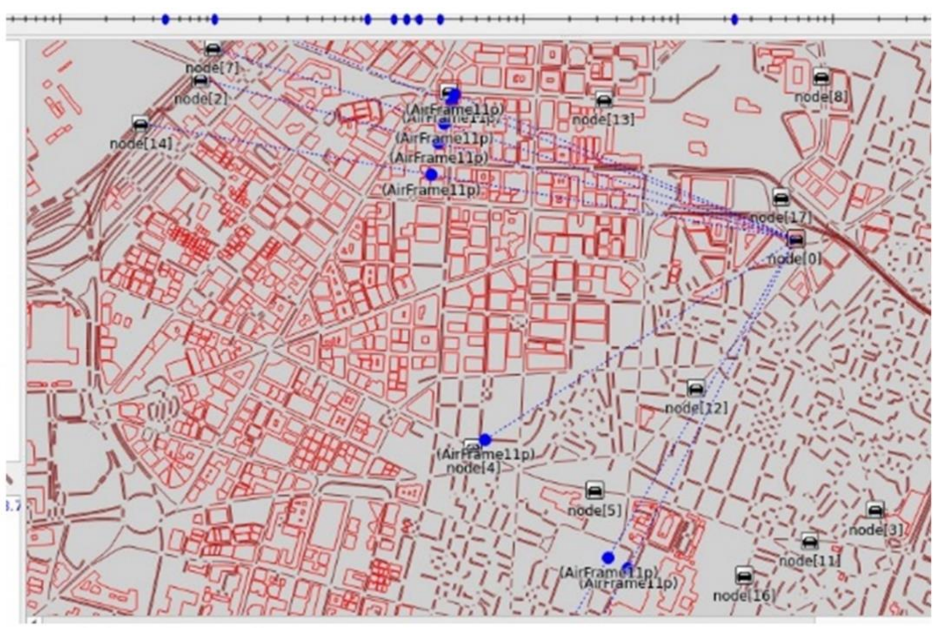

Figure 8.
V2V communication used by node 0 to send signals to other nodes.

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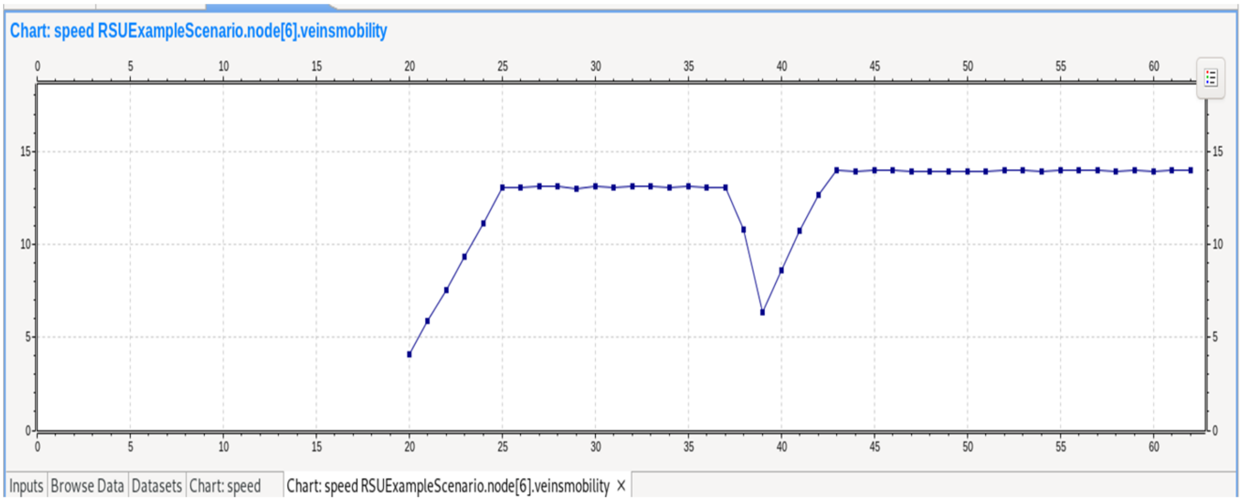

Figure 9.
Graphical representation of speed of node 6.

Figure 8 depicts node 0 facing congestion, where it starts sending V2V signals to all other automobiles and V2I signals to its nearest RSU to inform them of the incident. Consequently, other automobiles that received these signals modify their routes. Figure 9 shows the speed of node 6 before the congestion appears, then when the congestion appeared and node 6 received the incident alert, and finally after node 6 started to re-route accordingly. As shown in Figure 9, the speed of node 6 is not affected by the congestion. Thus, our simulation showcases that VANET can reduce traffic congestion on roadways while not affecting navigation times, which enhances the traffic management in ITS in smart cities.

6.3. Comparison between Veins and NS-3

Veins can precisely simulate traffic patterns in urban cities that are similar to real-life, such as dynamic traffic patterns, interactions among automobiles, interactions between automobiles and road infrastructure, and roadways [33]. Also, it employs a user-friendly interface with versatile visualization features. This allows Veins to be actively adopted in the assessment process of new technologies related to ITS development in smart cities.

On the other hand, despite that NS-3 has built-in wide range of networking protocols, it contains a smaller number of mobility models compared to Veins [34, 35]. Also, data collection in NS-3 is complicated along with its poor GUI, which makes it difficult to tailor for simulating different VANET scenarios [36].

7. Conclusion and Future Work

This paper highlights the vital role that VNs play in ITS management in smart cities. We employed Veins simulator to model various vehicular interactions for different traffic scenarios, which are necessary for offering perspectives on the development of effective ITS in smart cities. Also, we showcased, through our comprehensive simulations, that VANETs are essential for enhancing traffic management, decreasing incident response times, and maximizing roadway safety. Besides, VANETs can minimize the navigation times and mitigate traffic congestion, thus saving energy and yielding to eco-friendly ITS.

Furthermore, full real-life experimentation of VNs on a small scale, such as a selected roadway or region in a city, needs to be implemented in the future. This pilot study would be used to assess various initiatives proposed for the development of ITS. Through utilizing the results generated from this study, further progress in the field of ITS management could be achieved.

Transparency:
The authors confirm that the manuscript is an honest, accurate, and transparent account of the study; that no vital features of the study have been omitted; and that any discrepancies from the study as planned have been explained. This study followed all ethical practices during writing.

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