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A Software-Centric Evaluation of the VEINS Framework in Vehicular Ad-Hoc Networks

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***Abstract*—The Large Communication Substitution between vehicles to infrastructure (V2I) or between vehicles (V2V), called as Vehicular Ad-Hoc Networks (VANETs), in new Tale Intelligent Transportation Systems (ITS) are degree and stop developing for extensive traffic manage, highway safety, and driverless cars. VEINS is a simulator framework that couples OMNeT++ and SUMO, widely used for assessing performance of VANET protocols and network architectures. However, it was observed that no existing research reviewed VEINS applications, limitations, or emerging trends in a structured manner. In this paper we provide a software-oriented summary of VEINS-based VANET studies. This research adds a taxonomy-oriented classification of studies published from 2011 to 2022, focusing on IEEE Xplore, ScienceDirect, and Scopus categorized security, safety, and other VANET applications. It identifies some gaps, right from the scalability, and computational overhead aspect to the limited integration of the next-generation technologies like 5G, Blockchain, and AI. A well-defined article selection strategy, extensive data extraction, and a comparative analysis of published VEINS studies is followed throughout the study. Statistical analyses show a growing percentage of VEINS but also point out obstacles to its real world usage. Key Insights point to an emphasis on security and safety, with little focus on emerging technologies and real-world validations. This review adds value to the body of knowledge by (1) establishing a systematic taxonomy of VEINS-based research, (2) highlighting gaps in research and methodological limits, and (3) providing future research directions focused on VEINS scalability enhancement, real-world validation frameworks, and AI-enabled VANET optimizations. The study is expected to be a useful reference for researchers and practitioners who intend to improve VEINS-based simulations of VANETs and accelerate development in the field of ITS.**

***Keywords*—Software-Centric Evaluation; Intelligent Transportation Systems (ITS); OMNeT++/VEINS Framework; Vehicular Ad-hoc Networks (VANETs); Network Simulation; Traffic Modeling**

I. INTRODUCTION

The emergence of Vehicular Ad-Hoc Networks (VANETs) has become a cornerstone of modern Intelligent Transportation Systems (ITS) by providing real-time communication between vehicles (V2V) and infrastructure (V2I) to improve road safety, optimize traffic flow, and facilitate the operation of autonomous vehicles [1]–[3]. Simulation frameworks have become essential for assessing new protocols, communication paradigms, and network designs as VANETs continue to advance. Using these frameworks, VEINS (Vehicles in Network Simulation), which integrates OMNeT++ and SUMO (the Simulation of Urban MObility), is widely used because of the modeling of realistic mobility of vehicles and network interactions [4]. Although VEINS is extensively used in VANET research, the adoption of VEINS is inconsistent, with studies varying significantly in scope and methodology [5], [6]. In addition, prior literature does not offer a systematic review of the application of VEINS across various domains, especially with regard to security, safety, and new vehicular technologies.

Towards the elaboration of intelligent transportation systems (ITS), the rapid developments of vehicular techniques and wireless services led to the emergence of vehicular ad-hoc networks (VANETs) [7]–[9]. VANETs refer to a specific type of MANET in which vehicles communicate among themselves (V2V) and with roadside infrastructure (V2I), supporting applications that enhance road safety, traffic efficiency, and driving comfort. Simulation frameworks serve as crucial tools facilitating the exploration and validation of innovative vehicular networking concepts and have cashed into the potential of this vibrant field [10], [11]. One specific framework that stands out in this regard is the OMNeT++/VEINS framework [12], [13], which is popular among researchers for simulating realistic Vehicle Ad Hoc Network (VANET) scenarios due to its modularity, scalability, and ability to incorporate existing communication protocols [14], [15].

OMNeT++/VEINS is a framework that partners the powerful simulation core of OMNeT++ with VEINS, a set of modules for vehicular simulation [16]–[18]. It allows researchers to explore complex vehicular behaviors, mimic real-world traffic patterns, and test communication protocols. While this framework has been widely adopted, it is used inconsistently across different domains, with little attention paid to essential areas such as security, safety, and resource management in VANETs [19]–[21]. Therefore, a systematic review of its application is essential to collate existing data, highlight deficiencies, and suggest future research.

This study discusses a systematic literature review of the OMNeT++/VEINS framework for VANET research, which is based on those studies [22]–[25]. This paper analyzes articles published between 2011 and 2022 through the major academic databases: IEEE Xplore, ScienceDirect, and Scopus, and classifies existing works into three domains: aspects related to security, safety, or neither one. This taxonomy also draws attention to the popular research trends as well as the unexplored opportunities of the framework. Moreover, it presents a statistical overview of the research contributions, giving quantitative information about the distribution and focal points of the VEINS-based studies.

The results of this review would provide a complete guide for researchers and practitioners and would enable them to appreciate the pros and cons of the OMNeT++/VEINS platform in solving complex issues about VANETs. This work hopes to fill in the remaining research gaps and point the way to future development in vehicular networking, which ultimately caters to more robust and reliable applications of vehicular ad hoc network (VANET) as one of the pillars for modern intelligent transportation systems (ITS). This study plays an important role, comprised of the following contributions:

- It aims to comprehensively paper the most recent literature on the software-centric evaluation of the VEINS of the OMNeT++ in different VANET research studies, which covers articles published from 2011 to 2022 retrieved from top-tier academic databases.
- Taxonomy Development: A taxonomy for studies conducted on VEINS-based VANET is proposed focusing primarily on three domains, namely, security, safety, and neither security nor safety. This taxonomy offers a systematic view of the research landscape.
- Statistical Analysis: The analysis of the number of articles concerning databases and categories provides quantitative insight, identifying research trends and gaps.
- Highlighting Future Research Areas: By mapping out the literature in this domain, this study highlights potential avenues that underexplored areas in the context of the VEINS framework; as well as motivating implications for future research.
- Overview for Scholars: It can serve as a valuable guide for scholars and professional to understand current trends and development towards the OMNeT++/VEINS framework in VANET domain.
- Future Work: the study suggests that future work can involve the use of VEINS and the experimentation on the different (industry, university) levels in order to streamline the VEINS on the high level

This work is organized as follows. The background of VANET in terms of its features, components, communication methods, parameters, and characteristics is explained in section II. The methodology of this work is described in Section III. The results and statistical values of this work are presented in Section IV. The distribution of this article regarding database sources, and subcategories in the taxonomy is presented in Section V. Section VI contains articles' result and statistic information. The final section VII addresses the challenges and future research directions. Lastly, Section VIII ends this paper with conclusion and summary.

II. VEHICULAR ADHOC NETWORK (VANET)

An overview of V2V which are an important component of Intelligent Transportation Systems (ITS) that facilitates communication among vehicles Vehicle-to-Vehicle, V2V and between vehicles and existing static infrastructure (Vehicle to Infrastructure, V2I), as illustrated in Fig. 1. Vehicular ad-hoc networks, or VANETs, use communication of vehicles with each other in the area to provide better road safety, improved traffic management, and a higher quality of the driving experience through wireless communication technologies. An overview of the VANET architecture, communication paradigms, and applications is given in this section.

A. Architecture of VANETs

The architecture of Vehicle Ad-hoc Networking (VANET) is required to provide dynamic and decentralized communication

between highly mobile nodes. It generally consists of three key parts:

- Vehicles: Mobile nodes with on-board units (OBUs) and sensors that communicate with adjacent vehicles and infrastructure. Modern cars are increasingly connected with powerful computing and networking features.

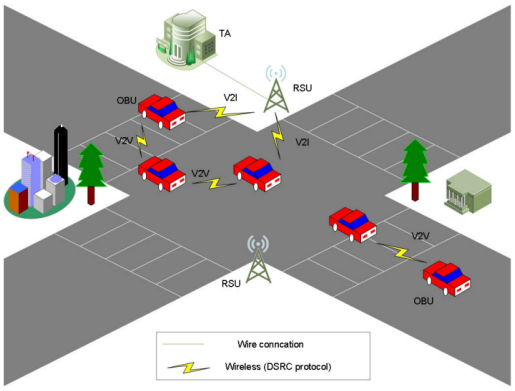

Fig. 1. Overview of VANET [26]

- Roadside Units (Antennon): These were infrastructure elements that were fixed by the roadside for supporting V2I communication. They increase communication coverage and connect vehicles to wider network systems like traffic management centers.
- Centralized Servers: For specific VANET scenarios, centralized servers accumulate vehicle and RSU data to implement large-scale analysis like traffic pattern detection, route planning, and emergency services coordination.

These modules are combined with layers to form a VANET architecture, thereby facilitating dynamic coordination with Intelligent transportation systems (ITS).

B. Communication Frameworks in VANETs

VANET communication is based on real-time communication, relying on a disseminated type of wireless, in which advanced wireless technologies exchange information between vehicles and road framework in dynamic situations. Important paradigms of communication are:

- Vehicle-to-Vehicle (V2V): in this mode cars can talk directly to each other within a limited range. This might enable V2V communication to become a crucial component in use cases such as collision avoidance, cooperative driving and traffic optimization.
- Vehicle-to-Infrastructure (V2I): This mode allows exchange data among the vehicle and RSUs and other fixed infrastructure. V2I communication is also essential for traffic signal coordination, electronic toll collection, and urban traffic management.
- Vehicle-to-Everything (V2X): To further enhance road safety, details here go beyond V2V and V2I by adding disciplines like interactions with pedestrians, cyclists, and cloud-based services as part of discrete vehicle signaling. Road Safety and Connectivity: It is a holistic approach to improve road safety and connectivity.

Dedicated Short-Range Communication (DSRC), Cellular Vehicle-to-Everything (C-V2X), and the emerging 5G networks provide technologies that support these paradigms in vehicular communication with low latency and high reliability.

C. Applications of VANETs

A VANET supports a range of applications grouped into safety, traffic management, and infotainment services:

- Safety Applications: Collision Avoidance: Alerts to maintain a safe distance from nearby vehicles, as well as cooperative braking mechanisms to prevent accidents. Emergency Vehicle Notification: More efficient routing of emergency vehicles through congested areas. Lane Change Assist: Alerts for blind spots and unsafe lane changes.
- Application of Traffic Management: Smart Traffic Signal Management: System to adapt the timing of traffic lights according to current conditions. Congestion Detection & Mitigation: Detecting bottlenecks and recommending alternate routes. Automated Vehicle Type Classifier: Automatic class determination of vehicles.
- Infotainment & Comfort Applications: Internet Connectivity: Enabling streaming and browsing capabilities for passengers. Location-Based Services: Providing real-time information about nearby facilities, parking spots, and fuel stations. Driver Assistance Systems Navigation guidance and traffic updates.

These applications showcase the transformative potential of VANETs to enable safer, smarter, and more efficient transportation systems.

III. Method

The key word used in database searching in this section was the ”framework of VEINS and its use in VANET”. We excluded the articles that utilized the VEINS framework but were not related to VANET from our survey. Additionally, the research material to be identified in this study would be part of an English-language publication specifically addressing the use of the VEINS framework in the VANET scenario.

A. Sources of Information

To extract and aggregate relevant studies from the literature, three academic databases were used: IEEE® Digital Library - a vast database and leading source of full-text content in electrical engineering, computer science, and electronics. ScienceDirect: A large collection of scientific articles across multiple fields. Scopus: A multidisciplinary database that covers scientific

and technical research across hydrocarbons, natural sciences, life sciences, engineering methods, and humanities and social sciences. The databases cover the studies concerning the VEINS framework in VANET and offer insights into various related methods.

B. Study Selection Process

To select studies for inclusion, we screened and filtered studies through both a systematic search and three rounds of inclusion/exclusion screening. Initial Screening: Articles not related to the VANET-based VEINS framework were filtered out. Second iteration: Titles and abstracts of the remaining articles were reviewed to remove unrelated studies. Iteration Three: We reviewed all of the full-text articles again for relevance. Each iteration used the same eligibility criteria set by the authors. Thus, ultimately selected studies were related to the VEINS framework in VANET for different topics as part of the utilized framework.

C. Search Strategy

On the IEEE Xplore, ScienceDirect and Scopus databases, searches were conducted using the search features in March 2022. Studies related to VANET were searched using various combinations of keywords. These search terms were VEINS, VEINS model, VEINS framework, VEINS OMNeT++, OMNeT++/VEINS, VEINS simulator, and simulation of vehicles in the network.

Logical operators ”AND” and ”OR” were used to combine the keyword ”VANET and then used other associated terms like Vehicular Ad-hoc Network and its variations. Using advanced search features, we specifically excluded document types that were irrelevant to our questions, e.g. short communications, letters, correspondences, and book chapters. Furthermore, some of the recent works were able to be captured by the search since we already mentioned that the VEINS/OMNeT++ framework is increasingly used in VANET studies. The exact query text can be found in Fig. 2.

D. Criteria of Eligibility

The eligibility criteria depicted in Fig. 2 were followed for the selection of articles in the final set. The criteria structured the VEINS-based VANET research into three broad classes; derived from an initial survey of literature. Exclusion Criteria: We excluded articles meeting any of these criteria: Retention on any type of network like MANET or FANET. It was not written in English. Articles that fit the VEINS framework utilization criteria were retained for subsequent analysis.

E. The data collection process

All eligible studies were reviewed, analyzed, and organized systematically to facilitate the screening and filtering process. Here’s how it worked: Fulfilling information needs based on preliminary categorization of articles by summarizing text into Excel and PowerPoint files.

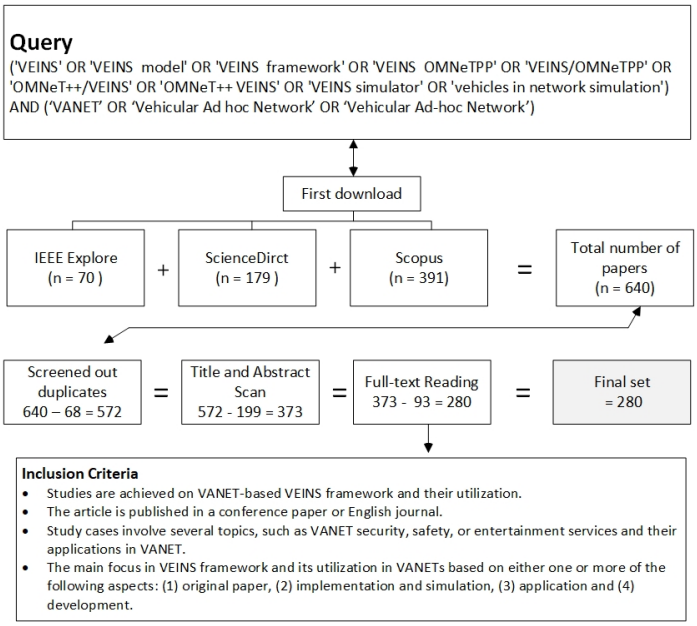

Fig. 2. Flowchart of Research Method

The authors conducted a full-text review of all articles, exhaustively making notes and highlighting to explain information concerning the extraction of topics. A proposed taxonomy was used to classify the studies into three high-level categories: security, safety, and neither security nor safety. Using this taxonomy, the articles were systematically categorized, allowing researchers to gain an integrative knowledge of studies and their utilization. The compilation provides valuable information on how the VEINS framework was developed and applied within the VANET context, as reflected in the final classification, which indicates how thoroughly the selected articles were explored.

IV. Results and Statistical Information of Articles

According to the databases, the first query search is formed by 640 articles, including 70 articles from IEEE Xplore, 179 from ScienceDirect, and 391 from Scopus. This study included articles published from 2011 to 2022 and was categorized into three different groups: A total of 68 duplicate articles were identified and removed in the screening process. After reviewing titles and abstracts, 199 articles were excluded, resulting in 373 articles for further consideration. A full-text review of the remaining literature excluded a further 93 articles, leading to a final selection of 280 articles. Selected articles were directly related to the application of the VEINS framework in VANET technology in different domains.

The articles were classified based on the taxonomy shown in Fig. 3, which emphasizes the main research streams associated with the VEINS framework and its general applications in VANET. This taxonomy covers the broad topic, grouping articles into three categories: Area of Study: Topics about security under the VEINS for VANET framework (61/280 articles). Safety Applications: 121/280 articles relate to safety aspects. Other: Articles that seemed unrelated to security or safety (98/280 articles). These categorized articles are the basis of a statistical analysis and discussion offered in the following sections.

A. Security Aspect

This subsection examines the security angle for the VANET-based VEINS framework. Security is a very grave issue in the case of VANET in the literature. The articles were categorized into three classes: Threat and Vulnerability, Functionality, and Requirements.

1) Threats and Vulnerabilities:

- Infrastructure: A Sybil attack was modeled in vehicular platoons and assessed to enhance operational efficiency for effective traffic management in vehicular network [27]. However under platoon maneuver attack, jamming, channel overhearing, and data packet injection these protocols April 15, 2020 IEEE 802.11p, and hybrid security based VLC protocol will used to secure and maintain platoon stability when platoon maneuvers. This approach proposed a new technique that can be used to detect Sybil attacks, by separating the vehicles into different clusters that removes the sybil nodes along with their certificates and location information. Static/dynamic selfishness, where intermediated nodes can forward other's tasks, was researched in [28]. Thus, a novel solution for identification of actions of smart attackers was proposed according to adaptive detection level [29].
- Probabilistic cross-layer intrusion detection system (IDS) that relied on a trained machine learning system and could achieve better than baseline detection of spoofing attacks was proposed in [30]. Towards this, they suggested a new speed based attacker position algorithm which is effective in infiltrating a Pseudonym Change Strategy (PCS) to enable multiple pseudonyms can mated to the same source [31] Zhou et al. To this end, [32] proposed an invariant-based distributed collaborative intrusion detection system, which aims to counteract betrayal attacks in vehicle networks.
- Wireless Interface: For several types of passes as random or fleet strategies; the analysis of man-in-the-middle attacks and degradation in the network performance [33]. This led [34] to investigate a lightweight based DD OS Flood attacks. The proposed anonymous method utilized a pseudonymous mechanism formulated based on the driving behavior of the drivers, wherein the eventual identity of the driver is hidden in the vehicular communication, as per the attacking capabilities that are achievable, as established in [35], provided the optimal level of privacy for the driving vehicles. A theoretical framework to determine the exact value of the threshold to trigger the operability of the fail-safe trigger [36] was developed in another effort for misbehaving vehicles. In this work, a scheme for privacy is proposed where the purpose of this study aims to determine the impact of the eavesdropping of the adversary on the overall system functioning based on the performance metrics in [37]. Another study proposed different Pseudonym Management Techniques (PMTs) on tracking success [38], where two adversary placement strategies were evaluated. This study considered threat source and security requirements for secure VANET applications, and proposed a generic testing framework [39]. Sharshembiev et al. (2018) studied the incidence of accidental misbehavior of vehicles by generalizing the weighted persistence broadcast mitigation technique to be suitable for the neighborhoods environment [40].

2) Solution:

- Blockchain: A trust management model and a blockchain-based authentication scheme are also proposed in [41] for the VANET system to enhance system security against inside attackers injecting false emergency messages. In [42], a addition-based aggregate pseudonym management scheme was proposed to provide the vehicles conditional anonymity using the Blockchain. Alternatively, a general approach of a permissioned consortium blockchain network equipped with smart contract functionality was designed to enable the management and issuance of the pseudonym in a security-preserving and privacy-respecting [43]. In [44], we proposed a user's Biometrics Blockchain (BBC) framework to ensure that the data shared among vehicles remains statuary. To enhance the integrity of the data and provide an immutable record, while deploying the system in a distributed framework [45], a blockchain-based decentralized authentication scheme is proposed. In [46], a secure distributed message-passing framework was proposed, which determine the trustworthiness of the source of the message by utilizing blockchain technology. District 6: novel of 5G vehicular network architecture based on blockchain technology included key elements between priority and reputation system with incentive mechanism that allows towards low-cost and scalability 5G vehicular network architecture.
- Entropy and Machine learning: A novel protocol misbehavior detection concept was proposed based on machine learning frameworks and entropy [47]. To increase network reliability and communication efficiency, a cluster-enabled cooperative scheduling approach based on Reinforcement

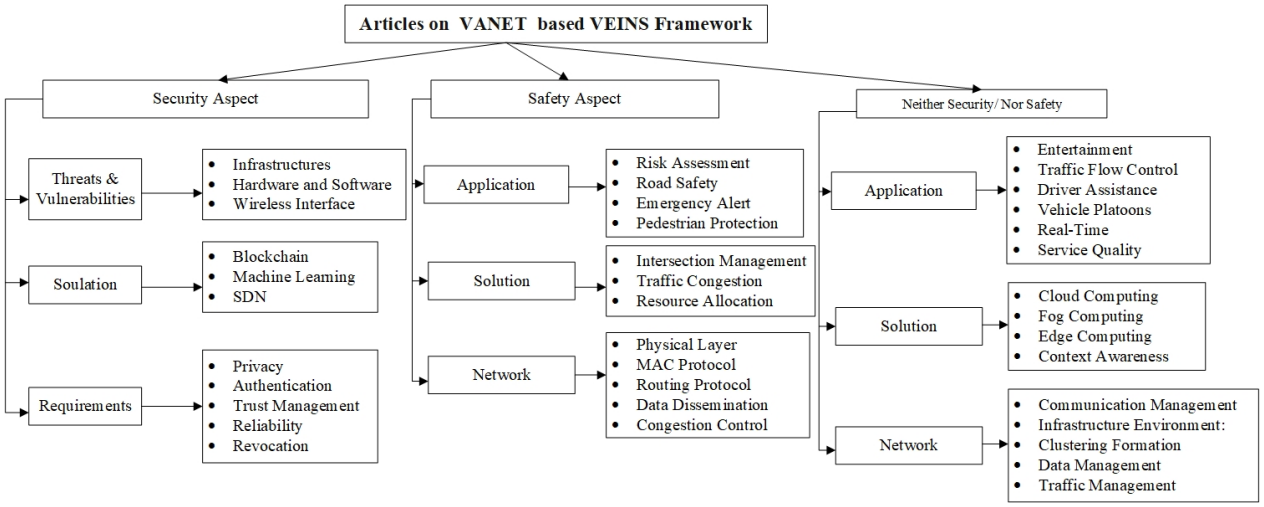

Fig. 3. Classification of Research Studies

Learning (RL) proposed in [48] that aspires to maximize information capacity. Sensory analysis intuitively takes messages that augment awareness and safety information, previous existing message clustering [49]. [50] was using AI to result in self-driving cars and collision avoidance.

- Software Defined Network (SDN): TFMD-SDVN, a scheme for identifying misbehavior in software-defined vehicular networks, was introduced in [51], and is based on the conceptual validity of an event resulting from legal or illegal nodes in the VANET framework. In order to establish a hierarchical hybrid trust management architecture, an efficient flow forwarding mechanism was proposed in [52]. Their work proposed a Trust-Based Distributed DoS Misbehave Detection (TBDDoSA-MD) to detect the DDoS misbehavior and to secure the Software-Defined-Vehicular-Network(SDVN) with vehicle trust values [53]. They introduced TB-EDA (Trust-Based Event Detection Algorithm), which uses trust values to identify whether a vehicle has been compromised or not by comparing the neighbor vehicles of the node's trust value with a predetermined threshold trust value. Using a central controller to schedule traffic signals leads to a higher efficiency due to better knowledge of intersection conditions and road traffic [54]. The SDN controller routed the traffic data load on segments of the road to reduce congestion between the vehicles in [55]. It offered a new way to get done of the SDN plane in special from the VANET point of view, to cope not only the road safety on highways but also on any other traffic lanes using the SDN plane : [56]. and proposed a smart ranking data offloading (SRDO) algorithm to optimize the RSUs and improving the quality of service [57].

3) Requirements:

- Privacy: A location privacy-preserving scheme with safety awareness where the communication area of the vehicle is diversified to prevent the continuous tracking of the location was proposed [58]. As per [59] a pseudonym dynamic change as security protocol compliant with anonymity and privacy relates to privacy of the driver and his/her vehicle either the driver works as the sender or sleep is the message receiver. This novelty is with limiting the area where beacons are communicated by a vehicle to alternatively evade tracking, i.e., in an extended [60]. An adaptive beaconing approach was applied to the proposed location privacy mechanism to ensure the Quality of Service (QoS) of road safety applications [61]. To cover all potential situations for change in behavior of vehicles in the traffic, a dynamic change of pseudonyms-based security protocol was introduced to enable drivers to maintain anonymity [62]. In [63], the authors proposed a pseudonym redressing and management strategy based on a Vehicular Location Privacy Zone (VLPZ). Advancements in location anonymity from mix-zones Anonymization based on generalization and differential privacy was offered for sensitive vehicular trajectories in [64]. A Cooperative Pseudonym Exchange and Scheme Permutation CPESP operation was proposed to secure user's privacy [65].
- The authors proposed a secure scheme based on elliptic curve cryptography that can be used to authenticate traffic emergency in VANETs and other applications in the automotive environment. An architecture for cross-regional node identity management based on hash chain and RF fingerprint theory was proposed, which can ensure the security of node identity and protect the non-replicated physical information identity authentication mechanism [66]. A Hash-chain-based identity authentication and privacy protection scheme [67] was proposed to simplicity the blockchain in space-air-ground integrated networks

(SAGIN) To enhance the efficiency of authentication and reduce communication overhead, a multi-signature scheme based on signature aggregation and batch message verification was proposed [68]. The hybrid approach was thus proposed to combine both the group signature-based approaches and pseudonym-based approaches in the VANETs to avoid respective limitations for the privacy-preserving authentication approach [69]. They proposed a security schema (see [70]) based on Elliptic Curve Diffie-Hellman (ECDH) and Elliptic Curve Digital Signature Algorithm (ECDSA) to guarantees the RSU identification and the fact that the vehicle authenticate the message before signing it. As a potential remedy for this, privacy-enhanced localized hybrid authentication scheme (PLHAS) was devised via modeling on two public key cryptosystems, CL-PKC, PKI that gives way to ensuring the role separation and overcoming the centralized dependency. A proposal of an authentication scheme using the combination of Tamper Proof Device Based (TPDB) and Road Side Unit Based (RSUB) schemes to minimize the overhead of the system is presented in [71]. Improved the use of the logic of subjective two-position verification mechanism to address misbehavior detection in a generalized framework [72]. In [73], a Sybil attack prevention mechanism for vehicular ad hoc networks (VANETs) based on Sybil attack detection and anonymous authentication scheme was devised.

- Trust Management: Therefore, a novel trust management scheme of self-organized VANET was proposed where an VANET entity-based and data-based hybrid method was presented. To implement VRM in VANETs, a centralized reputation system for forwarding behavior and message creation behavior has been proposedin [74]. A Vouch+ scheme was study for improving shared location information accuracy with cryptographic primitives, achieving a higher speed mobility awareness [75].
- Reliability: In [76], the authors introduced a self-reliant trust management to ensure the message reliability based on nodes credit. To guarantee best reliability for data dissemination for specific delay constraints, a widely used solution where unipolar orthogonal Code-based Reliable multi-hop Broadcast (BCRB) was employed varying from channel states [77].
- Revocation: The paper [78] proposed a Smart Certificate Revocation List Exchange (SCRLE) that divides a Certificate Revocation List (CRL) into pieces and separates it and distributes these pieces in the vehicles. To enable rapid update of revocation status for vehicles in a shared blockchain ledger, a revocation and authentication framework was proposed using blockchain [79].

B. Safety Aspect

The following section presents the exploitation of the VANET-VEINS Framework based on Vehicle Safety. We divide this class based on application, solution, and network taxonomy.

1) Application:

- Risk Assessment: In Highly automated driving (HAD) a global risk indicator was proposed by local data coming from infrastructures or surrounding vehicles [80]. The fuzzy risk-based decision model was proposed by [81] to meet the requirements of completeness, reliability, and higher robustness. A warning system for emergency vehicles named Emergency Vehicles EV warning based on V2I communication was defined and designed in order to minimize the potential risks for accidents [82].
- Game Theoretical Approach
- Road Safety: In order to solve the data dissemination problem a decentralized stochastic solution was proposed using two mechanisms of game-theoretical [83]. The order of security index was predicted pattern using an Adaptive Neuro-Fuzzy Inference System (ANFIS) [84]. To minimize the potential of collision in an overtaking interaction process, a cooperative overtaking assistance the persistent system was proposed [85]. As a case, vehicle movement characteristics are defined by the performance of the Studied V2U model, and investigates the road traffic flow needs required over the road net work for turning fraction estimation and traffic counting [86]. Elleuch et al. proposed a Cooperative Road Hazard Detection Persistent System (CopRoadHazDPS) system to determine a road hazard by the mean of V2V and V2I communications [87]. In a real time context, the DTA problem is solved to efficiently distribute the vehicles over the road network [88].
- **Emergency Alert**: Conditions of emergency alert were evaluated to be deployed in certain conditions of road traffic in the Zilina city, where L2 broadcasting and L3 routing was evaluated to transmit an emergency warning messages [89]. A Dynamic Partitioning Scheme (DPS) scheme respectively in light traffic and dense scenarios [90]. Status of traffic lights changed to decrease responding time of the emergency vehicles using the communication technologies [91]. A synergistic health intelligent emergency response system was proposed to handle passengers under situations of abnormal health so as to decrease the receipt of the first emergency treatment [92]. A draft for an automatic emergency corridor framework was designed for such kind of emergency where it is effectively required to clear the way for manually dispatched emergency vehicles [93]. A new approach was developed through multiple sensors, to collect data in vehicle trips for emergency situations or for proposing dangerous [94]. For accidental situations, a decision making module with the adjusted in-

formation processing was also discussed [95]. The number of detected collisions were proposed to use as a metric for congestion control, in order to reduce the congestion effect by controlling the beacon creation frequency [96]. To support efficient and fast multi-hop broadcast communication in VANETs, a dynamic backbone assisted MAC (DBA-MAC) scheme was proposed [97]. An EPVS (Enhanced Priority VANET Scheme) was proposed based on both data type and reliable distance range [98]

- Person Protection: here using mobility and communication, OMNeT++ and Vadere was joined in the speed represented like communication is depended on the other hand to mobility and mobility where dependent on mobility and vice versa [99]. A-Ambulance communications (A2V) was proposed to implement communication between ambulances and other non-emergency [100] to assist in rescue missions Boualouache et al.proposed a Hybrid Pseudonyms Distribution Method (HPDM) to provide location privacy of drivers using not only RSUs but also vehicles to achieve the pseudonyms distribution [101]. Before the maneuver is started, the overtaking assistant is claimed to predict whether a crash will occur and sound an alarm to the driver [102].

2) Solution:

- Intersection Management: The performance of a distributed traffic control strategy was explored to study the dynamics and the effectiveness of the newly proposed traffic control protocol [103]. Experimented at intersections to improve safety, real time databases and Vehicle-To-Vehicle (V2V) communication are used to reduce calculation time and decrease the risks of collisions [104]. An adaptive decentralized congestion control protocol was proposed to monitor the accuracies required by Intelligent Transportation System (ITS) applications [105]. An algorithm for counting vehicles stopped at a traffic light based on count request message propagation [106].
- Traffic Congestion: To avoid travel time and decrease the total emissions of CO2, traffic congestion detection system was evaluated and simulated by [107]. Identified and reduced a vehicular traffic congestion by [108]. ANGA: An algorithm to quantify and detect the traffic congestion level designed by completely distributed manner to enable every car in the network found (Milojevic and Djuric 2014). Based on V2V and vehicle-to-RSU (V2R) communications, two new methods were proposed to find a suitable candidate for traffic management [109]. Then, a security protocol and a high-level system architecture were tailored to the particular case of congestion detection based on vehicle-to-infrastructure (V2I) type communication [110]. For the transport system, a TRAFFIC solution was proposed to estimate the traffic congestion level for the maximum flow of vehicles [111]. A smart electric vehicle charging management and an innovative dynamic traffic congestion pricing system for the internet of vehicles were introduced in an urban smart city environment by [112]. A vehicle-to-vehicle congestion avoidance mechanism was proposed to reduce their trip times by detecting levels of real-time congestion and rerouting vehicles [113]. As per the map of the city based on that a servers hierarchy is formed, Distributed Infrastructure-Free Traffic Optimization System (DIFTOS) was proposed in urban setups [114]. Existing approaches to cover the trade-off between channel congestion control and coverage needs are based on the Multiple Metric Power Control (MPC) [115]. A routing algorithm was proposed to handle congestion and car CO 2 emission issues through the rerouting process [116]. To make use of up-to-date traffic data for dynamic route reassignment, a new scalable dynamic route planning method was developed [117]. [118] introduced and simulated a cognitive radio technology for archiving vehicle communication throughput demands. To decrease the average trip time, an INCIDEnT solution was introduced to identify, disseminate, and manage congested roads [119]. In a related work, a solution was proposed for the detection and control of congested roads for reducing fuel consumption, average trip time, and CO2 emission with respect to inter-vehicle communication [120]. A new strategy has been introduced to provide Current Traveling Time (CTT) for each city street, which determines the shortest route from origin to destination in VANETs communication [121].
- Resource Allocation: The resource allocation scheme was proposed in [122]). The presence of severe impairments and preliminary results for platooning applications were presented. Under congested channel conditions, a relevance-aware resource allocation mechanism was proposed for decentralized vehicular networks [123]. In this regard, a proximity-aided broadcasting service was proposed in network-managed device-to-device (D2D) communications in a multi-hop fashion [124]. The external infrastructure with vehicular cloud scenario was considered by [125] who proposed an allocation resource and efficient search protocol without supporting the infrastructure. In addition, resource sharing was supported utilizing mobile cloud [126] without assisting the outer framework in vehicular network.

3) Network:

- Physical Layer: Packet loss and end-to-end delay were investigated as two dominant elements affecting performance of mobile nodes regarding the key communications factors, namely, power of transmit and frequency of beacon [127]. Similarly, A RA-TDMAp protocol was presented which combines the properties of CSMA/CA and TDMA-based Overlay Protocols for Vehicles Pla-

tooning [128]. Two Markovian Models Employed V2V [129] Two Markovian models were suggested to investigate performance on IEEE 802.11p EDCA mechanism for entertainment applications of vehicle-to-vehicle (V2V) applications. The authors proposed an Line-of-Sight (LOS) probability based on [130], which covers rural and urban cases. The communication in vehicular environment is proposed to be performed using hybrid handover algorithm to merge the LTE networks and multihop clustering based on IEEE 802.11p to achieve low end-to-end delay and high data packet delivery ratio (PDR) [131]. The control channel being used was also analzyed in [132] for the beaconing performance of IEEE 802.11p. For example to enhance Received Signal Strength (RSS) for VANET at about 700 MHz a lower frequency was utilized as shown in [133]. [134] adaptively tuned CCH time interval and contention window size depend on channel load and vehicle traffic. The VCPS perspective has been investigated in [135]. The two-ray interference model was simulated by [136].

- Medium Access Control (MAC) Protocol: A Carrier sense multiple access with collision avoidance (CSMA/CA) and two TDMA-based overlay protocols were used to perform extensive simulations with transmit power, number and size of lane occupied for deriving empirical models [137]. An application-oriented metric was used to evaluate the MAC protocol responsiveness and was shown to constrain the time cause of semi-persistent collisions in a large-scale system-level simulation [138]. For infrastructure communications, it was shown in work that a schedule based TDMA scheme can be defined which dynamically reallocates unused TDMA time slots [139]. The MAC protocol that is based on the congestion behavior of 1609.4/IEEE802 in highway and urban environments. 11p was exhibited by different vehicle density [140]. A beacon messages based scheduling algorithm was proposed based on adjusting road traffic according to the CCH interval and scheduling the priorities based safety messages [141]. An evaluation of the 802.11p MAC protocol with CCH interval settings and different vehicle densities was proposed in [142]. A dynamic MAC protocol was proposed which adjusts the length of SCH and CCH intervals based on load conditions and vehicle density [143]. A connection-level scheduling algorithm was proposed to which scheduled the start sending time of each transmission [144]. The MAC protocol was designed for urban context. An adaptive multi-channel allocation for safety communication was introduced through real-time communication traffic condition in order to support dynamic multi-channel utilization [145].
- Routing Protocol: In a system performance, a modified hybrid routing scheme was proposed by incorporating a greedy forwarding system using Advanced Greedy Hybrid Bio-Inspired (AGHBI) [146]. In order to select the optimal path for vehicles, a 2-Hop routing algorithm based on the multi-objective Harris Hawks optimization algorithm was proposed [147]. In urban scene, a routing approach was proposed to explore the correlation between global node density and network availability, achieving interconnections between source and destination vehicles [148]. An Enhanced Greedy Perimeter Stateless Routing (GPSR) protocol was proposed by introducing a multipath feature for performance increment and packet loss decrement [149]. One of the most efficient routing algorithms has been optimized by [150] to minimize average stoppage time and average delay waiting in VANET. A Mobility Prediction Based Routing Protocol (MPBRP) was proposed where the user's intention from the positioning systems was used to recover paths, packet transmission and find new neighbors [151]. Related work include vanet with a new probabilistic multimetric routing protocol (ProMRP) to achieve acceptable performance, namely = average end-to-end packet delay and average percentage of packet losses network in VANETs [152]. Aiming that, its position and the functioning of the routing protocol were enhanced for selection of next forwarding node, without any alteration on value of beaconing frequency [153]. To facilitate multimedia distribution, an adaptive opportunistic multicast routing with multiple criteria (MAOTRP) was proposed to dynamically adjust the operation of the routing mechanism in vehicle-to-vehicle telescreen (VVT) [154]. The bus-trajectory based street-centric (BTSC) routing algorithm was proposed under the guidance of two new ideas, including path consistency probability and street consistency probability, namely, only using the major relay buses to carry messages and deliver them to the destination [155]. Proposed a mechanism to reroute vehicle in case of accident scenarios using scenarios based simulations of VANET [156]. Referring to vehicular networks in using artificial bee colony algorithm and clustering algorithm, proposed a unicast routing protocol based on quality of services [157]. A beacon information independent geographic routing approach was proposed during previous of route discovery to increase the worth of the distance to the data packets for forwarding while decreasing the numbers of broadcast [158]. The routing protocol GeoWave proposed improved the network performance and network reliability while minimizing the Carbon Dioxide (CO) and controlling the traffic blockage in context of high traffic density of urban area scenario. A contention-based geographic routing protocol described a Dual-Mode Optimum Distance (DMOD) routing protocol to serve applications of unicast messaging [159]. A new method for real-time detection of node misbehavior was presented [160], where the real-time detection was achieved via the selective flow sampling and entropy change. We proposed

a two communication modes based on a geographical routing protocols to achieve an expected charging slot reservation for VANETs, in [161].

- Data Dissemination: [162] proposed a realistic mobility model based on Bus dissemination; a bi-directional coupled technique is utilized for service discovery protocol that uses the networks of public bus A scheme of emergency packets dissemination was proposed by vehicles equipped with both cellular LTE wireless and DSRC capabilities [163]. A reliable emergency message dissemination (REMD) scheme to guarantee a specific reliability for message dissemination for different types of channel conditions while meeting delay requirements [164]. Counter-based, probability-based and simple flooding techniques were implemented that needed broadcasting techniques to the required network to disseminate information efficiently [165]. An adaptive broadcast range was used for specific applications [166]. was the selective forwarding mechanism based data dissemination technique. For low vehicle density environments, a data transmission control system has been proposed for the retention of spatio-temporal data (STD) [167]. An fully distributed approach was proposed in an urban scenario [168] that enables contributive dissemination of collection by collecting and querying reply messages containing the data acquired from vehicles navigating within a specified destination region. Because of this, a DISCOVER protocol was proposed to collect and distribute the interest data in a metropolitan area for it to be timely and efficient by using an individual network structure [169]. In [170], a local knowledge based data dissemination protocol was proposed for fairness based on Nash Bargaining concepts from game theory. They proposed an infrastructure-less Geocast protocol for this purpose in which to route the messages only to vehicles within the relevance zone but at a less overhead cost [171]. A multi-hop based data dissemination approach was proposed to achieve scalable broadcast, with no additional communication cost through traffic regime estimation [172]. [173] proposed a markov chain-based protocol for data dissemination. An data dissemination protocol in vehicular networks (DRIVE) was proposed, which provides message delivery under sparse and denser networks [174]. An Adaptive Data Dissemination Protocol (AddP) was presented as a solution to reliability for message dissemination in an efficient way [175]. An alternative data dissemination protocol based on map splitting was proposed in [176]. Using communication metrics and vehicular traffic, the impact of road traffic warning message dissemination strategies was assessed by [177]. Video road-casting protocol [178] For high-definition video patterns, a Road-Casting Protocol scheme was proposed to distribute their contents. A work proposed (ABDDis) scheme to locally (local 1^{st} hop) beacons utilization only [179]. A content-centric networking based vehicle-to-vehicle communication scheme under Dedicated Short Range Communication (DSRC) was presented in [180]. A new geographic broadcast suppression mechanism built to rebroadcast to nodes, to assign a higher priority to within special forwarding zones [181]. The construction of a message exchange protocol, named CarAgent, was presented for information collection and dissemination of floating vehicular data [182]. Simultaneously determining which bidirectional channel is the fastest way to reach the Linking Layer (i.e., the path of shortest travel time) and designing it for dissemination of packets was also carried out with two purpose laws [183]. Therefore, a virtual backbone based on minimum stable CDS was proposed to ensure guaranteed fast and efficient broadcasting [184]. And they proposed an efficient mobile content delivery scheme in Content Delivery Network (CDN) according to dissemination protocol [185]. Common methods to deal with broadcast storm and network partition issues are explained in a novel story–carry–forward (SCF) scheme [186]. One infrastructure-free Precise Point Positioning (PPP) based self-sufficient Cooperative Positioning (CP) system was proposed without needing the infrastructure [187].
- Congestion Control: A new decentralized congestion control algorithm was proposed that manipulates the transmission power according to a density estimation based on the driving speed of the vehicle [188]. An approach using a Decentralized Congestion Control (DCC) reactive control method to control load on a channel was also considered [189]. An adaptive multichannel scheme was proposed based on the current communication traffic state, enabling flexible usage of multichannels [190]. We presented a distributed cross-layer congestion protocol to aggregate and bind on congestion level [191]. A DisTraC protocol to mitigate the average travel time for the vehicle was proposed with low communication overhead for a traffic congestion control problem [192]. To improve the network performance and reliability, a non-cooperative game approach was used to assist selfish users demanding high data transmission rates [193]. The concept of contention window and hybrid power control to ensure the safety and stability of interconnections within a vehicular network was proposed in a congestion control scheme [194]. It was studied [195] that a decentralized congestion control would investigate the effecting in dense traffic scenarios based on an collective perception for sharing the sensor data.

C. *Neither Security/ Nor Safety Aspect*

However, the majority of these research publications presented in VANET papers are mostly concerned with matters of security and safety. Yet, many of these articles do not have a basis of security or safety concerns. It's worth noting: this

category has one mission — to need more throughput than safety applications do. This category is analyzed according to the taxonomy of application, solution, and network.

1) Application:

- Entertainment: The behavior of video streaming application was predicted by analyzing the capability of video streaming [196]. The study had implemented different methods for studying video quality in urban [197] case. An event-based simulation framework for video delivery, by means of user experiments focused on video transport in vehicular ad-hoc networks (VANETs), were presented by applications named GatcomSUMO and GatcomVideo [198]. Several coding parameters provided by the HEVC video encoder were investigated in order to enhance the perceived quality of the transmitted video in VANETs [199]. As for online video service, a cellular network and VANET were synchronized through a combined downloading paradigm [200]. A multilayer approach for a specific session of video delivery with a bag of simulation results [201] offering an integrated simulation framework at physical, MAC, application and user levels. In the context of altruism: A mechanism was proposed to choose the least congested service [202].
- Traffic Flow Control: They proposed an algorithm that calculates the utility for each data communication such that it is biased towards driving the User Equilibrium (UE) to the System Optimal (SO) state [203]. The Dynamic Traffic Assignment (DTA) problem was thus proposed and simulated to distribute vehicles on the road network dynamically and more efficiently based on the vehicles' origins and destinations [204]. TESLA-like schemes and highway scenarios were evaluated using (forwarding) GeoNetworking over ETSI Contention. The protocols were analyzed, focusing on the performance of communication routing protocols in VANETs in Madinah city primarily through autonomous or human-driven vehicles. [205]. The location-based and information-centric (LoICen) architecture was proposed [206] to reduce the broadcast storm problem and improve the content requesting mechanism.
- Driver Assistance: A Fuzzy-decentralized congestion control oriented on traffic was proposed for CAMs delivery ratios acceleration in congested traffic flows [207]. Whereas a prediction strategy was proposed to limit tracking over particular areas so that the improvement of the tracking accuracy would be maintained [208]. The collective perception concept was proposed, with the supporting foreseen self-announcing vehicles and local perception sensors [209].
- Vehicle Platoons: In practice this has been studied through a cyber-physical restating of the problem in order to ensure proper tracking of the dynamical properties of such a platoon, or the arrival, merging and joining [210]. Implement an intelligent decision making framework for intelligent vehicle platooning, which would outperform the non cooperative solutions in certain comparison parameters from [211]. There were proposed an energy-efficient platooning with the assistance of Gray Wolf Optimization (GWO) based platooning management [212]. The proposed manager was PSOAR (Particle Swarm Optimization Adaptive Relay) [213] to provide better services to owners. A platoon management protocol has been developed for the system of Cooperative Adaptive Cruise Control (CACC) based on wireless communication [214].
- Real Time : In ref. [215] a real time method was proposed to cooperatively track target vehicles. A self-organizing time division multiple access (STDMA) has been explored for use in industrial applications to identify its usefulness for real-time purposes [216]. The proposed shield for vehicular network is a CBQoS-Vanet protocol which is responsible for ensuring the QoS metrics through an efficient QoS criteria in highway scenario using a beecolony-based algorithm and clustering technique [217]. To ensure the shortest paths with the least travel time as real-time traffic condition information becomes available (e.g., travel speed, congestion, etc.), a real-time path planning algorithm was designed [218]. In fact, the following is a series of the works where the system identified(purpose of the paper) is an Integrated vehicular network aiming to address vehicle tracking and provisioning of unicast service on a single framework architecture [219]. The authors of [220] proposed an Ego-Vehicle Interface (EVI) method for online evaluation of complex interacting cooperative driving systems. A Distributed Data Gathering Protocol (DDGP) was introduced in highway and urban seniors for data buffering delay tolerant and real time collection [221].
- for non-safety applications, service quality is made superior by employing an exceptional dynamic transmission opportunity assignment (DTAS) approach. A dynamic TXOP parameter limit assignment (as a service quality) to the vehicles has been proposed in [222]. To mitigate this, the authors have developed Altruistic Service Channel Selection (ASSCH), through which less congested channels are chosen for V2V non-safety applications [223]. Sun et al. analyzed the CUT algorithm and proposed a graph-based cooperative downloading mechanism to download the useful data from the Internet and re-distribute it to the vehicles in an almost optimal way [224]. After which, a channel model specifically for V2V communication was presented covering a multilink highway scenario and line of sight (LOS). The total utilized bandwidth of a multicast tree was modeled using Min Steiner Tree and Min Relay Intersections Tree methods [225]. A cross-channel interference was introduced in multichannel vehicular networks that concerned spectral emission masks at the physical and packet levels [226]. A lightweight beaconing based

commercial services advertisement protocol is proposed in [227] for a congested multi-lane highway scenario.

2) Solution:

- Cloud Computing: The intelligent traffic light control algorithm studied in [228] is based on the cloud computing, the core objective is to dynamically manage the execution of traffic lights in line with the actual condition of road in real-time. In [229], the authors studied the feasibility of vehicle platoons as mobile vehicular clouds. In [230], a Position High-Speed Vehicle Detection Algorithm (PHVA) is proposed to detect higher-speed vehicles with the help of a vehicular cloud server. In addition, grouping vehicles and offering resource based on clustering technique [231] is presented. Using fog-enabled vehicular computing-based crowd-sensing scheme were planned.
- Fog Computing: A data aggregation framework was introduced using fog computing to minimize traffic information in the vicinity at the edge of vehicular network [232]. In this case, to analyze effects on traffic conditions, traffic lights, and intersections in the urban VANET routing performance, authors [233] proposed an Intersection-based Distributed Routing (IDR) strategy. A heterogeneous two-tier fog architecture based data collection approach was proposed [234] to enable privacy and security-preserved data crowd sensing among smart vehicles. The authors in [235] explore the design of a decentralized Intelligent Transportation System (ITS) architecture that distributes its management tasks between central and decentralized entities. This enables fine-grained over a wide range of geographically distributed resources, where Fog Computing (FC) was integrated with Software Defined Networking (SDN) components for provisioning location-aware services in VANET [236]. An energy-efficient based multicast routing protocol with bandwidth and deadline constraints [237].
- Edge Computing: A PSO-based offloading mechanism was proposed [238]. A QcFND (Quick Fake News Detection) framework was proposed to leverage the technologies [239].
- Context Awareness: A PCS (Pseudonym changing scheme) based adaptive privacy and context aware method in order to prevent system wide awareness of the fast changing traffic condition [240]. A developed Trust Evaluation And Management (TEAM) framework for evaluation, management, and design of trust models in diverse environments.

3) Network:

- Communication Management: This section presents the first analytical model proposed in the literature to analyze infrastructures [241], inspired by the theory of a Stochastic Petri Net (SPN), which takes into account mobility and network parameters. A swarm intelligence based approach was also proposed to maintain traffic flow the formation and evolution of platoons during congestion and collision avoidance practices [242]. The latter, to achieve increased performance in VANET, was proposing for the requirement of optimization with a genetic algorithm for RSU deployment that makes an optimal selection of specific number of RSUs in a given area [243]. As the fifth generation mobile communication(5G) the architecture of A LPWA, these considerations integrate to be a model of their were integrated and analysed [244]. A distributed MobiVNDN framework was introduced in [245] to address the reduced communication performance of interplanetary communication (with VNDN) due to the impact of wireless technologies (wireless links) and mobility. For scheduling the prioritized responding vehicles was proposed [246]. Polygon-segment intersection verification was performed over digital surface models and a 3D road network was constructed with multi-level communications in mind [247]. An obstacle model based optimization for speeding up the ray-tracing computation at the physical layer was proposed in [248]. Data up to October 2021. The works proposed temporal metrics and tools along with temporal graphs to make models of VANETs applications [249].

  The static instantaneous surrounding was generated using the empirical based method of Rician K-factor approximation in two urban regions of Australia, New South Wales [250].
- Clustering Formation: Dynamic Single-hop Clustering Algorithm (DSCA) was introduced to enhance clustering performance [251]. To include a self-location computation algorithm and a strategic game-theoretic algorithm, the research proposed a Destination- and Interest-Aware Clustering (DIAC) mechanism, as reported in [252]. A collection process presented and examined a hybrid networking architecture and protocol [253]. In an urban scene, a connectivity prediction based dynamic clustering (DC) model was proposed by Cheng et al. The authors proposed a hybrid method that combines both trust and stability factors to elect trustworthy cluster heads [254]. Enhancing Safety Messages Broadcasting in Cluster (NSSC) focusing on three consecutive process such as broadcasting of safety message, collision avoidance and cluster formation was proposed in [255]. A clustered mobility-aware data collection network was proposed to mitigate the impact of mobility and node density on the data collection stations [256]. Based on the realistic number of wireless-equipped vehicles, a new three-steps model is presented in a link [257]. A multi-hop clustering algorithm which is new in the literature has been proposed by [258]. Directional communication offers improvements in throughput and energy efficiency over beamforming; however, it reduces coverage in both space and time order making it an unclosure idea for low-latency, high data rate communication and ultra-

reliable towards millimeter wave (mmWave) communication, which has been proposed with integration with the popular direct short-range communication (DSRC) standard [259]. A multicast communication architecture was proposed in [260] to transmit the warning messages from the two communication protocols on all vehicles and infrastructure. We proposed a novel cellular-5G VANET architecture to enhance urban quality of service [261]. In an advanced LTE d2d cluster [262], two LTE-based vehicular networking algorithms were proposed that support transmissions of safety message.

- Data Management: With QoS provisioning, a data offloading scheme that allows a vehicle to instantaneously offload its data to RSU using V2I or V2V communications was proposed [263]. The QoS for multimedia transmission was evaluated using the VoIP application on the lite-a configuration environment [264]. Expected delivery delay: Vehicle-assisted data delivery and trajectory based data forwarding was presented with expected delivery delay in [265]. Using a Floating Car Data (FCD) from a single Original Equipment Manufacturer (OEM) available as a base, traffic disturbances were detected [266]. A caching scheme was proposed in the in-network layer to request a file or as cache node to serve other nodes [267]. And an architecture of system services for information-centric networking has been introduced to implement [268]. In this respect, a range of solutions were proposed for efficient real-time FTP information collections [269]. A hybrid method that outperformed a dedicated cellular radio access offloading was show, which trades off in order to reduce complexity and maximise efficiency [270]. A fully distributed Floating Car Data (FCD) collection was proposed to exploit the heterogeneous network [271] since both DSRC and LTE standers were provided. An urban scenario was defined to test the proposed Floating Content (FC) scheme [272].
- Traffic Management: In [273] it was developed an adaptive and distributed traffic management system, in which the local view of traffic congestion along with V2V communication is used. Ref. [274] presented an implementation and design of a distributed vehicle traffic management SYstem (dEASY) conceptualized on three layers architecture method, knowledge consumption, knowledge generation and environment sensing and vehicle ranking. A different study conveyed through VANETs in Moving Towards Road Safety Parameter, Variable Speed Limit (VSL) [275] Traffic Management and Road Safety researched a dynamic informed decision-making module that recommended the driver on accident scenarios based on the superimposition context [276]. [277] proposed a traffic organization solution which took advantage of the V2I communication to search for alternative paths. In contrast, data of vehicular traffic measurements was proposed to be collected, for the application of real-time incident detection [278].

V. Distribution Results

The data base source and subcategory in the taxonomy create a set of article distribution in various categories, which is demonstrate here.

A. Database Source Distribution

As depicted in Fig. 4, many research articles come from three database sources. This articles typeset in three-term taxonomies, security, safety and neither security/ nor safety facet.

The number of our studied articles in IEEE explore is 44, i.e. 10 articles on security aspect, 17 articles on safety aspect, and 17 articles on neither security and safety aspect. 70 articles can be searched on ScienceDirect (security aspect, safety aspect, nor security/ nor safety aspect) articles as a whole. Out of 166 articles retrieved from Scopus, 40 articles (24.1% of total 166 articles) fall under security aspect while 75 articles (45.2% of total 166 articles) fall under safety aspect and 51 articles (30.7% of total 166 articles) fall under neither security/nor safety aspect.

Total number of studies articles from Scopus is 166 as mentioned in Fig. 4, which is reduced by $\frac{166-44}{166} \approx 73\%$ and $\frac{166-70}{166} \approx 58\%$ respectively against IEEE Explore and ScienceDirect database sources.

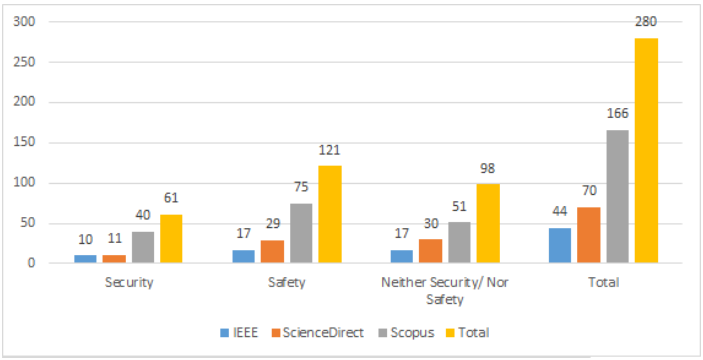

Fig. 4. Number of studied articles in varying taxonomies based on article and database source

B. Taxonomy Subcategories Distribution

We present here a ratio of various studies we chose in this work by means of subsections of titles in the taxonomy. The searched sources on the database are shown in Fig. 5. There are three elements in the title: security, safety, neither security/ nor safety. Each one could be broken down into a number of subcategories. These subdivisions point toward the path for most future research in this area. Many scholars will likely use these studies as baselines for future study as such.

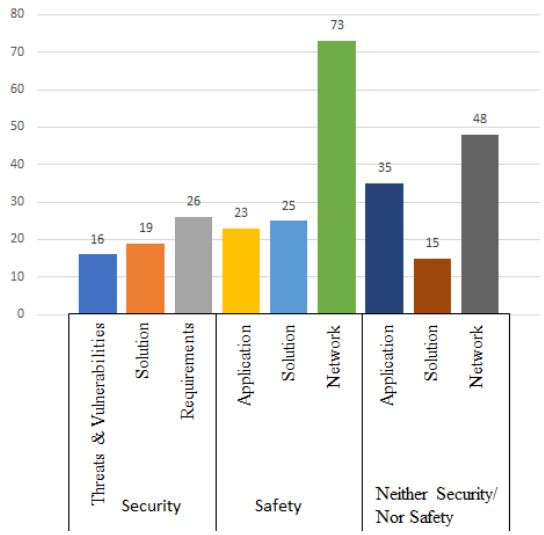

Fig. 5. Distribution of Subcategories in the Taxonomy

In security section, the total articles under threats and vulnerability are 10, which covers 5, 3 and 8 as far as infrastructure, hardware & software and wireless interface are concerned respectively. The solution literature for the identified solutions comprised of: 19 articles, 4 machine learning 7 blockchain 8 SDN A total of 26 articles addressed general needs while the data requirement related to privacy, authentication, trust management, reliability and revocation were 9, 10, 3, 2 and 2, respectively.

In terms of safety, the number of articles studied per application is 23, which includes risk assessment 3 articles, road safety 6 articles, emergency alert 10 articles and person protection 4 articles. There are 25 studied articles from solution: 4 for intersection management, 16 for traffic congestion and 5 for resource allocation. Article distribution of the studied articles from the network (74 studied articles: 10 articles for physical layer, 10 for MAC protocol, 17 for routing protocol, 28 for data dissemination, and 8 for congestion control).

The 35 articles studied in this respect from a safety perspective were 8 enjoyment, 5 traffic flow management, 3 driver assistance, 5 auto groups and 7 real-time service quality. Such articles provide the following content solutions (2 on context awareness 6 on fog computing, 2 on edge computing and 5 on cloud computing,).

VI. Results and Statistical Information of Articles

This study reviews the articles that used the OMNeT++/VEINS framework to conduct VANET research for the period of 2011 to 2022. Following a rigorous screening process from the major academic databases: IEEE Xplore, ScienceDirect, and Scopus, a total of 280 relevant articles were analysed. Articles are classified into three overarching categories based on whether their focus is security, safety, or neither security nor safety.

A. Quantitative Analysis

The first query resulted in 640 articles. After you remove 68 duplicates and 199 articles based on title and abstract irrelevance, you conduct a full-text review. This last step yielded 280 articles, showing a wide-ranging interest in the VEINS framework across differing research communities. The distribution of articles per database was:

- IEEE Xplore: 70 articles
- ScienceDirect: 179 articles
- Scopus: 391 articles

The categorized final selection includes:

- Security-related: 61 articles
- Safety-related: 121 articles
- Neither security nor safety: 98 articles

B. Detailed Statistical Overview

An overview of articles is the best way to overview reasearch trends and gaps. The safety domain has received the most attention in terms of research, which emphasizes the importance of safety applications in VANET. Articles centering on security made up a small but significant portion, indicating persistent issues in vehicular network security.

- Security Domain: This category contained articles that examined complex cryptographic algorithms and intrusion detection models.
- Safety Domain: This domain had a wide range of applications, including collision prevention systems, dynamic traffic management, etc., demonstrating a wide coverage of research on improving vehicle operation safety.
- Not Security but Safety: This heterogeneous category contained analysis of multiple network performance and communication of the underlying VANET infrastructure as well as more unorthodox use cases such as infotainment systems, indicating potentially extenuated boundaries of VANET applications.

C. Highlighted Trends and Gaps

1) Emerging Trends:

- Merging of Emerging Technologies: There is a noticeable trend of merging new technologies such as blockchain, 5G communications, and edge computing into the VEINS framework. Such integrations would enable security improvements, data throughput maximization and minimization of latency which are of particular importance for real-time applications in the VANETs sector.

- Machine Learning Adoption: The utilization of machine learning approaches to increase prediction abilities and increase decision-making procedures in the VANET setting. This is particularly evident in traffic flow optimization, anomalous detection, and adaptive network management systems.
- Sustainability — A number of recent studies have been taken on by smart solutions for transportation to target environmental issues and decrease emissions and improve fuel efficiency. The VEINS framework allows exploring and testing of more sustainable vehicular technology in terms of the environment.

2) Research Gaps:

- Little Research into User Privacy and Data Security: Even though security components have been introduced and deployed, there is still a dire need to research user privacy and data security in the face of the an increasing entanglement of vehicular networks.
- There are many underexplored areas, including dynamic management of traffic and real-time response systems in highly congested urban settings, that have significant potential impact for the future.
- Limited Focus on Scalability: Few studies investigated scalability problems of simulated networks, particularly those that can realistically emulate heavy urban traffic patterns at a high scale. This gap is essential in establishing the validity of VANET technologies in real-world environments.
- Integration Hurdles: There is insufficient elaboration on the practical challenges faced when integrating VEINS within real-world vehicular systems. The studies are is mostly theoretical or isolated topics without regard to large scale system integration issues.

VII. Discussion: VEINS Framework in VANET

VEINS (vehicles in network simulation) is a popular open source simulation framework that connects the OMNeT++ discrete event simulator with the SUMO (simulation of urban mobility) simulator. It helps to model and analyze VANETs for realistic traffic and communication conditions. This forum addresses the major aspects, advantages, and limitations of the VEINS framework, focusing on its use in VANET studies.

A. Key Features of VEINS Framework

- Integration with OMNeT++ and SUMO: VEINS integrates OMNeT++, widely recognized for its powerful communication network simulation capabilities, and SUMO, which simulates detailed traffic dynamics. The addition of mobility provides a limitation for the main vehicle-based purpose of the integration thus making this integration helpful for construction purposes.
- Realistic Mobility Models: VEINS integrates real life traffic scenarios, such as the control of traffic lights, the configuration of an actual road network, and vehicular behaviours, through the capabilities of SUMO. Users can recreate urban, suburban and highway environments with different vehicle density and traffic patterns.
- Musical Application Formats and Application Sessions: VEINS is modular to its core, allowing researchers to integrate their own protocols, mobility models, and applications. Such extensibility allows it to be tailored for a variety of research objectives, from safety-related applications to (next generation and advanced) congestion management.
- V2X Communication Support: VEINS natively supports Vehicle-to-Vehicle (V2V), Vehicle-to-Infrastructure (V2I) and Vehicle-to-Everything (V2X) communications simulation. Researchers can study latency, packet loss, and throughput in a range of network conditions.
- Integration with Emerging Technologies: Moreover, the framework can be easily extended to facilitate novel technologies such as Cellular Vehicle-to-Everything (C-V2X), 5G communication, and edge computing, which renders it relevant for modern VANET research.

B. Strengths of the VEINS Framework

- High Fidelity Simulations: VEINS provides high realism of vehicular mobility and network communication which is a key aspect for the development of real-life VANET applications.
- Open-Source Accessibility: VEINS is open-source, allowing easy adoption, community development, and adaptation.
- Comprehensive Documentation: VEINS also comes with detailed documentation, tutorials, and a significant user community to support researchers in using it effectively.
- Protocol Design Flexibility: VEINS features a modular design enabling the direct evaluation of new communication protocols for specific VANET applications by researchers.

1) Challenges and Limitations:

- Computational Complexity: Simulating massive VANET scenarios with high traffic densities and considerable number of communication nodes could be resource-intensive and require high processing and memory capability.
- Limited Built-in Models: Although VEINS is extensible, the built-in models may not cater for every emergent technology and scenario and thus an extra effort is surely demanded by researchers.
- Integration Overhead: The co-simulation of traffic (SUMO) and communication (OMNeT++) introduces challenges and overhead due to syncronization, which can impact the accuracy of simulation.

- Scalability Concerns: Scaling simulation to simulate entire cities or regions, however, is still a challenge, especially for real-time simulation needs.

C. Future Prospects

The VEINS platform will be also evolving over time by introducing state-of-the-art technologies and methods. Future advancements will likely center on:

- VGML network continues to grow, with support for more than just wireless in the future
- Artificial intelligence (AI) integration for autonomous decision-making in VANET.
- Scalability and efficiency for simulation of large-scale urban environments
- Extensions for multi-modal transport systems and Internet of Vehicles (IoV) support

The VEINS framework is to the best of our knowledge the cornerstone tool for performing VANET research as it provides researchers with an opportunity to develop cutting edge solutions that can be applied in the real world for ongoing issues facing modern transportation systems. As VEINS addresses its limitations and embraces emerging trends, it is ready to play a critical role in the future of vehicular networking."

VIII. Conclusion

This paper provides a systematic literature review and software-based evaluation of the VEINS framework concerning VANET research. We mapped VEINS-based research using IEEE Xplore, ScienceDirect, and Scopus studies spanning 2011 to 2022, distributing them into three main categories based on the areas of security, safety, and additional VANET implementations. By performing this classification, we identified important research gaps, such as challenges in the scalability of these methodologies, computational overhead for large-scale simulations, and limited integration of novel technologies, such as 5G, block chain-based technologies and AI-driven optimization techniques. To add, our study draws attention to the limited real-world validation of VEINS simulations, which increases the doubts whether VEINS is suited for real vehicular networking.

Although VEINS is versatile, it has multiple limitations that must be overcome to ensure wider adoption and future improvements. The heterogeneity of biological systems makes large-scale simulations light work for today's computers, which cloud-based simulation frameworks and parallel computing approaches are quickly solving, hybrid modeling techniques are rapidly addressing. Moreover, even though VEINS offers a modular architecture, it does not have built-in support for next generation technologies (e.g., edge computing, AI-based decision making, and ultra-low latency communication in 5G networks). Existing gaps must be addressed to ensure that VEINS can be more scalable, adaptive, and relevant to real vehicular systems.

Methodologically, we acknowledge potential bias arising from the fact that we performed a systematic review across only three databases (IEEE Xplore, ScienceDirect and Scopus), and restricted our selection to English-language publications. It would be beneficial to consider a wider array of databases in future reviews, including ACM Digital Library and SpringerLink, to better represent the current state of VEINS research. Moreover, the taxonomy-based classification could at best be applied in a binary fashion, in which existing literature could be placed in the proposed categories, while also ignoring not only the interdisciplinary overlaps in research spread across VANETs. However, to accommodate the emergence of hybrid VANET simulation techniques in future work, the proposed framework may also describe different features and capabilities.

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