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Study and Analysis of Prospective Applications for Vehicular Ad-Hoc Networks (VANET) in Intelligent Transportation Systems



Abstract: - Vehicular Ad-Hoc Network (VANET) is a type of Mobile Ad-Hoc Network (MANET) that enables communication between vehicles and between vehicles and road-side base stations. Its purpose is to facilitate efficient and safe transportation. Vehicular Networks offer a diverse range of services, ranging from safety-related warning systems to enhanced features. Navigation mechanisms and information and entertainment applications. Extensive research is currently being conducted to investigate the Issues affecting to vehicular communications encompass network architecture, protocols, routing algorithms, and security Problems. To encourage novice researchers, we present a paper providing a summary of Vehicular Ad-hoc Networks. VANETs communications consist of vehicle-to-vehicle and vehicle-to-infrastructure interactions that rely on wireless local area network technologies. The unique combination of candidate applications, resources, and the environment differentiates VANET as a distinct field within wireless communication because of their distinct Vehicular ad hoc networks (VANETs) are highly appealing to both academia and industry due to their notable features, such as dynamic topology and predictable mobility. In this paper, we present a comprehensive analysis of the key elements of VANETs from a research viewpoint. This paper focused on the fundamental structure of the text begins by examining networks, then delves into research issues and general research methods, concluding with an analysis of the challenges and applications of VANETs in Intelligent Transportation System.

Keywords: Wireless, Vehicular Ad-Hoc Network (VANET), Mobile Ad-Hoc Network (MANET), VANETs Applications, Intelligent Transportation System (ITS), Vehicle-to-Vehicle (V2V)

I. INTRODUCTION

Now a day, wireless networks have been developed into a very important medium in the field of data communication. For the period of the last two decades an incredible improvement has been occurred in the area due to the technological advancement in Vehicular computers and wireless data communication devices. In the recent adoption of multiple 802.11 wireless standards resulted in a significant growth in the number of wireless data networks. Wireless LANs are widely used nowadays, and the cost of wireless equipment is steadily decreasing. Currently, 802.11 adapters or access points (APs) may be obtained for almost nothing. As a consequence of the widespread adoption of the 802.11 standards, academics and the business sector are exploring for alternative alternatives for wireless technology. Mobile ad-hoc networks (MANET) have lately gained a lot of interest. The development of vehicular ad-hoc networks (VANET) is a potential application for mobile ad-hoc networks. A MANET is a self-forming network that can operate without the requirement for centralized control. Each node in an ad hoc network functions as both a data terminal and a router. Nodes in the network connect wirelessly with others within their radio range. VANETs are basically subsets of MANETs [1]. The hierarchy of wireless ad-hoc networks show in Figure 1.

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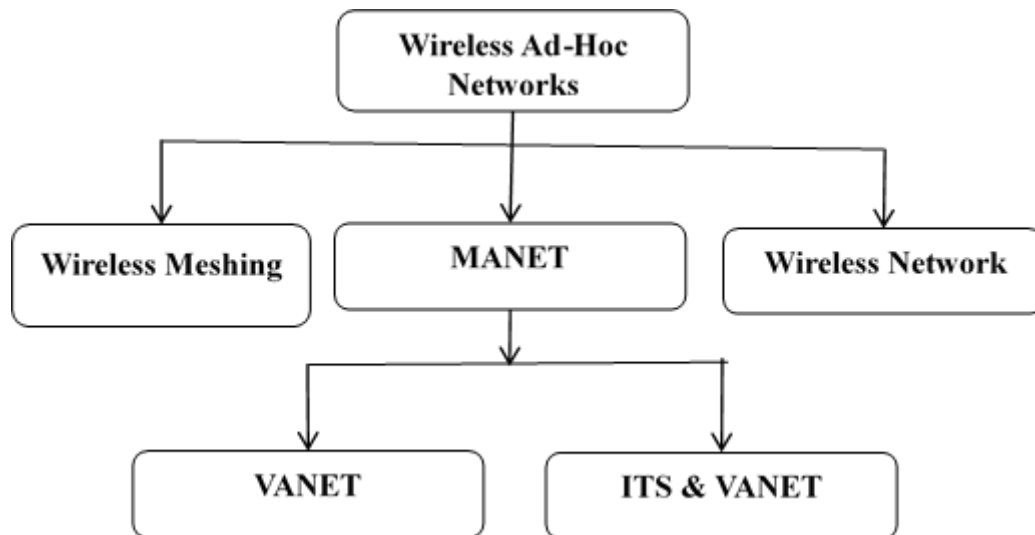


Figure 1: Hierarchy of wireless ad-hoc networks

1.1 Vehicular Ad-Hoc Network(VANET)

A Vehicular Ad-Hoc Network, or VANET, is a technology that is based on the mobile ad-hoc network concept. The moving vehicles are referred to as nodes, which form a mobile network. Thus, VANET are primarily designed for communication between vehicles and permanent equipment. We may say that VANET transforms vehicles into wireless nodes, enabling them to link to one another in close proximity to form a large network. If a vehicle falls out of range of the signal, it will disconnect from the current network, allowing additional cars to join and build mobile Internet. Direct wireless connection between vehicles allows for data sharing even when there is no Communication infrastructure includes base stations for cellular phones and access points for wireless networks [2]. Vehicular networks are a rapidly evolving technology for delivering and developing new and classic applications. It is defined by changes in topography, increased traffic, and vehicle communication. The movement and location of the vehicles are primarily utilized to define VANETs. VANET architecture is primarily utilized to provide communication between cars and between vehicles and roadside infrastructure equipment, resulting in the following possibilities, as show in Figure 2.

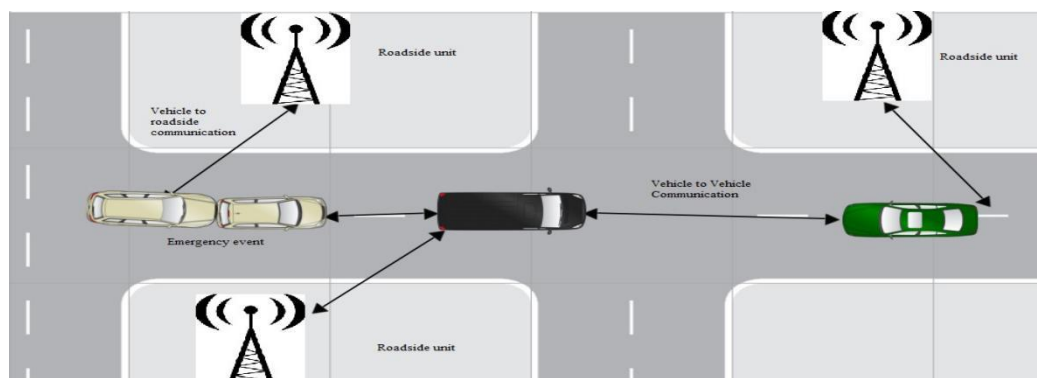


Figure 2: Vehicular Ad-hoc Network Architecture

- **Vehicle-to-Vehicle (V2V) communication-** It enables direct communication between neighboring cars without relying on roadside facilities, and it is mostly utilized for safety and security.

- Vehicle-to-Infrastructure (V2I) communication- It enables a vehicle to interact with a roadside infrastructural unit, allowing the vehicle to acquire information about other cars from the infrastructural unit's data storage application.
- Hybrid architecture combines Vehicle-to-Vehicle (V2V) and Vehicle-to-Infrastructure (V2I)- In this setting, a vehicle may It can interact with stationary roadside units via single or multi-hop connections, as well as directly with infrastructure units. Wireless links are made so that they may converse with cars located far away.

II. VANET APPLICATIONS

Vehicular applications divided into following categories

1.Safety applications- Safety applications are primarily used to monitor roads in a vehicular environment, including vehicle movement, roadside environment, road curves, road surface area, and so on. Road safety applications can be classified as follows:

- Real-time traffic: The RSU is primarily used to store traffic data in real time, and its availability is limited to on-demand requests. As a result, it will be able to address issues such as traffic congestion and information about crashes on the side of the road, allowing it to broadcast an emergency alert to all vehicles.
- Cooperative Message Transfer: Communication among vehicles through cooperative message transfer will aid in the safety of other vehicles. The main concern with message transfer is its efficiency and delay. Vehicles now have automated features such as emergency braking systems, which are used in an emergency to avoid accidents.
- Post Crash Notification: The post crash notification includes the broadcasting of a message regarding the accident that has already occurred in an area, which will be broadcast by the vehicles involved in that accident, not only avoiding road congestion, but also providing help to them as soon as possible and allowing the car to be towed as soon as possible to control traffic jams.
- Road Hazard Control Notification: The vehicles will send a notification message to all trailing vehicles in that area about the hazardous road condition, which may include landslides or information about the road's curve.
- Cooperative Collision Warning: A warning message is sent to vehicles that have the potential to collide, requiring them to change their path to avoid the collision.
- Traffic Vigilance: The cameras are installed on RSU so that they can continuously monitor traffic, allowing traffic police to keep an eye on driving violations or noncompliance with traffic rules.

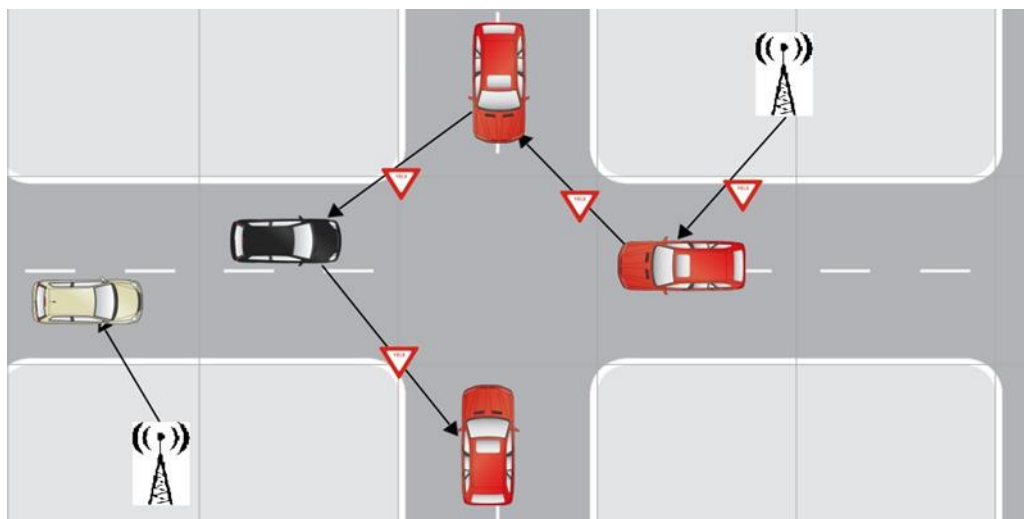


Figure 3: Emergency Situation Notifications

2.Commercial applications

Commercial applications are used to provide entertainment-related media files and services, such as audio and video. Commercial applications can be classified as follows:

- Remote Vehicle Personalization/Diagnostics: Remote vehicle personalization allows the driver to download and upload vehicle settings and diagnose them using information provided by the roadside infrastructure unit.
- Internet Access: The RSU acts as a router, providing internet access to the vehicles.
- Digital map downloading: Drivers download digital maps into their personalized vehicles so that they can receive continuous guidance while driving on unfamiliar roads. It can also provide other useful information about the food stations, petrol pumps, etc.
- Real Time Video Relay: Relay time video relay is a live video that serves as a source of entertainment for drivers. As a result, on-demand movies are provided based on the driver's preferences.
- Value-added advertisement: Value-added advertisements are provided within their communication range, without the use of the internet. These services provided information about restaurants, stores, and petrol stations so that they could attract customers.

3.Convenience apps

These applications are concerned with traffic management, specifically controlling the traffic that causes congestion in order to efficiently provide drivers with a congestion-free path to their destination [3]. The convenience applications can be classified into:

- Route Diversions: Diverting the route based on the information provided about congestion and accidents, so that a congestion-free path is taken.
- Electronic Toll Collection: Electronic toll collection is primarily used to collect tolls electronically from vehicles traveling along that route. These electronic tolls use GPS to generate receipts for toll rates via wireless links to vehicles. This application not only saves time for customers but also makes it easier for toll operators.
- Parking Availability: A notification message is sent to vehicles informing them of the availability of parking space, making it easier to find a parking spot and taking less time overall.
- Active Prediction: Active predictions are primarily used to provide pre-information about the topology of the road, indicating how fuel usage can be optimized by adjusting the speed of the vehicles, as well as to assist the vehicles in controlling the vehicle and making decisions.

4.Productive Applications

Productive applications are essentially extensions of other applications, but they also have their own set of important features. Productive applications can be classified into:

- Environmental Benefits: According to the research program AERIS, real-time information relevant to environmental conditions is generated, and this data is used to create green transportation that should be accepted by the transportation system's users and operators. The AERIS research program is working on V2V communication by implementing a multi-model approach to check the connections between vehicles so that they can provide information about the negative impact of transportation services on the road surface [4].
- Time Utilization: Using time becomes difficult when we are traveling and get stuck in traffic jams, so a basic requirement is the internet, which will assist the driver in utilizing time while waiting for the traffic to clear.
- Fuel Saving: Vehicles can save fuel by not stopping at the toll to pay and instead waiting for 5-10 minutes. As a result, not stopping at the toll booth to pay saves a certain percentage of fuel.

III. PROBLEMS & ISSUES OF RESEARCH

VANETs provide a novel and difficult environment for developers and communication engineers. There are many trendy issues for scholars to study, including:

A.Mobility modeling: Traditional ad-hoc networks normally assume restricted node mobility, with nodes being portable devices carried by users such as laptops, PDAs, smart mobile phones, etc. Mobility is usual in VANETs, and it is measured in miles per hour rather than meters. Vehicles obey the same road rules and regulations, resulting in consistent mobility patterns. Furthermore, because two vehicles stay within communication range for a couple

of seconds, it is an ongoing research topic to build a rich topology model [5] for VANET that differs from typical network topologies that need considerable interaction between the transmitter and receiver.

B. Routing protocols: Routing is important in VANET applications, but traditional network routing protocols are incompatible with this unique vehicular environment because vehicles move at high speeds, resulting in rapid changes in network topology and failing to establish end-to-end connectivity between source and destination nodes [6]. Researchers and engineers are developing strong routing algorithms to handle the VANET environment, ensuring high throughput and higher packet delivery ratios.

C. Scalability issues: One of the primary obstacles associated with the implementation of VANETs is operability, both in extremely light and heavily loaded networks [7]. VANET is designed to function in both low-density regions like roads and highways and high-density areas like cities and metropolitan areas with frequent traffic congestion and major crossroads. Researchers and developers may face challenges in designing scalable protocols and managing the number of active nodes (vehicles).

D. Security frameworks: Distributed untrustworthy nodes in vehicular networks must collaborate with one another and with the RSU [8]. Security concerns are a big concern in the VANET environment since nodes connect with one another via wireless transmission. Any modification in network information made by a fraud node may result in significant damage to vehicle drivers and passengers, as well as partitioning the network and decreasing overall performance. As a result, developing a solid security [9] solution for the VANET network that can dependably suit the different demands of the applications with the least participation of untrusted nodes may be an important research subject.

E. Quality of Service (QoS): Supporting QoS over VANETs remains a difficulty when present routing pathways become unavailable due to changes in node velocity, node location, network structure, or distance between vehicular nodes [10]. Network engineers and researchers have challenges in optimizing VANET capacity for message delivery and developing adaptive QoS routing techniques to build new routes efficiently [11].

F. Broadcasting: Broadcasting continues to be a prominent study area of interest for VANET researchers since a considerable percentage of messages delivered in VANETs are broadcast messages [12]. Effective and co-operative broadcasting algorithms are of worry for the researchers and developers to circulate safety and routing information both in the low density automobile locations and in the crowded metropolitan places where huge number of private cars are traveling on.

IV. RESEARCH METHODOLOGY

Effective research technique in VANETs is necessary to assess the performance of various architectural methods, protocols, algorithms, and applications [13]. Such techniques allow researchers and developers to identify limitations while also ensuring the availability of fresh suggested alternatives to the aforementioned issues. Because VANETs have the potential to be huge in size, introducing new technology into them requires extensive research, and the experimental implementation is quite costly. Before introducing a product to the market, two key processes are required: (1) simulation analysis and assessment, and (2) field operational testing [14]. This section introduces several models that serve as the foundation for techniques, followed by discussions on simulations and field testing.

A. VANETs have four sub-models: driver and vehicle, traffic flow, communication, and application [15].

(i) Driver and Vehicle Model: This model captures the behavior of a single vehicle. This behavior should take into account two primary factors: driving styles and vehicle features, such as aggressive or passive drivers and sports cars.

(ii) Traffic Flow Model: This model optimizes the road network by considering interactions between cars, drivers, and infrastructures. The authors of categorize traffic flow models as microscopic, mesoscopic, or macroscopic based on criteria such as depth of detail.

(iii) Communication Model: This model is crucial in research approaches for facilitating data transmission amongst road users. Due to several considerations, such as communication layer performance,

(iv) Application Model: This model is beneficial for market launch as it addresses the behavior and quality of cooperative VANET apps. This kind of model is important for two reasons: (1) Different car manufacturers provide different functionality and visuals for cooperative apps. (2) Prioritization of information and alerts is necessary when many cooperative applications exist simultaneously [16].

B) Simulation Methods: Simulation is undoubtedly an important step before using new technologies in VANETs. The simulation of VANETs involves two components: a traffic simulator and a network simulator.

(i) Traffic Simulators: To assess ad-hoc network features and protocol performance, traffic simulators produce location and movement data for a single vehicle in a VANET environment. In [17], the authors discuss various current traffic simulators in detail, such as SUMO (simulation of urban mobility) and VISSIM (modeling of vehicle location and movement, including city and highway traffic).

To simulate and assess VANET functioning, a decent network simulator should include characteristics such as a comprehensive mode, efficient routing protocols, and communication standards and conduct a comparative analysis of network simulators, including GloMoSim (global mobile information simulation) and NS-2 (the most common simulator for IP-based wired and wireless networks) [19].

C) Field Operational Testing: While the simulation technique contributes significantly to the study of VANETs, it does not accurately represent the actual vehicular environment. To address these difficulties, researchers have focused on field operational testing (FOT), which tries to test and assess these applications on a larger scale and over a broader variety of real-world settings. Such testing may bring the VANET system closer to the market and provide economic value. Because of the significant financial expenses and the large number of partners, FOT continues to rely on accurate simulation findings. On the contrary, FOT data may increase the validity of network models and the performance of protocols. FOT includes four key characteristics: (1) genuine system components, (2) real cars and traffic, (3) all stakeholders, and (4) a vast and diverse fleet [20].

V. RESEARCH CHALLENGES AND RESULT

Based on our prior examination of VANETs, we may conclude that they are an excellent self-organizing network for the future intelligent transportation system (ITS). Although researchers have made significant progress on the VANETs [19] study, there are still certain hurdles to solve and topics to examine further (e.g., communication, security, applications, stimulation, verification, services, etc.) [19, 20]. VANETs differ from MANETs in terms of communication, security, privacy, and wireless technologies [8]. For example, network connections may not remain steady for an extended length of time. To boost communication performance, researchers explored the optimal use of existing infrastructure, such as roadside units and cellular networks. Although certain particular VANET issues have been resolved, many important research challenges have only been partly addressed [7]. Researchers need to dig deeper to address these difficulties. In the following discussion, we will highlight the major problems [14].

(i) Underlying Limits and possibilities: From a theoretical standpoint, very little is known about the underlying [9] constraints and possibilities of VANET communication. We feel that preventing accidents and reducing resource use are both significant theoretical research concerns.

(ii) Standards: The original IEEE 802.11 [3] standard does not match the criteria for stable network connection, and the current MAC settings of the IEEE 802.11p protocol are inefficiently designed for a high number of cars [18]. Researchers need to focus more on standardization.

(iii) Routing Protocols: Researchers have presented effective routing protocols and algorithms such as CMV (cognitive MAC for VANET) and GyTAR (greedy traffic-aware routing). However, the critical challenge is to design good routing protocols for VANETs communication with high mobility and dynamic topology [12].

(iv) Connectivity: The most significant aspect of VANET communication is managing and controlling network connections between vehicles and network infrastructures [10]. The primary difficulty in creating vehicular communication is to achieve adequate delay performance under the limits of vehicle speeds, high dynamic topologies, and channel bandwidths [11].

(v) Cross-Layer: To accommodate real-time and multimedia applications, one option is to construct cross-layers between original layers [11]. Cross-layer protocols prioritize flows and applications across many levels. Following an analysis of the performance indicators, the authors of [8, 12] discuss the relevance of cross-layer architecture in VANET.

(vi) Cooperative Communication: In [10], the authors regard VANETs as a sort of cloud known as mobile computing cloud (MCC), while in [17], the authors describe a broadband cloud in vehicular communication. Researchers are facing a crucial difficulty in bridging the gap between vehicular and Internet clouds for vehicle management applications.

(vii) Mobility: Because vehicle networks are mobile, the topology changes often. Furthermore, the movement patterns of cars using the same route will show substantial relationships [12]. In [17], the authors discuss the importance of mobility in vehicular protocol design and modeling.

(viii) Security and Privacy: Reference [17] provides several options with severe flaws, and the dominant solution still depends on "key pair/certificate/signature." Key distribution is a crucial solution for security procedures, but it might be challenging due to different manufacturing businesses and driver privacy concerns [12]. Additionally, balancing security and privacy is a significant difficulty in meeting efficiency requirements.

(ix) Validation: It is required not only to evaluate the performance of VANETs in real-world scenarios, but also to find previously unknown and crucial system aspects. Altintas et al. suggest using field operational tests (FOTs) to address validation challenges in various situations. However, performing FOTs might be challenging due to the complexity of the system and its technical components [10].

Table 1: Safety-Oriented Applications

Name	Description
Intersection violation warning	It warns drivers when they are going to pass over a red light
On-coming traffic warning	It helps the driver during overtaking manoeuvre
Electronic brake warning	It reports to the driver that a preceding vehicle has performed a sudden braking
Vehicle stability warning	It alerts drivers that they should activate the vehicle stability control system.
Post-crash notification	A vehicle involved in an accident sends warning messages in broadcast to approaching vehicles
Traffic signal violation warning	A roadside unit sends messages in broadcast to warn drivers of potential violations of traffic signals
Lane change warning	It helps drivers to perform a safe lane change

Table 2: Convenience-Oriented Applications

Name	Description
Electronic toll collect	A vehicle establishes uni-cast communication with a toll gate roadside unit and pays the toll without stopping.
Parking availability notification	A vehicle asks to a roadside unit for a list of available parking spaces, and the roadside unit sends the list to the vehicle
Congested road notification	A vehicle in a congested road sends information in broadcast to other vehicles

Table 3: Commercial-Oriented Applications

Name	Description
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Remote diagnosis	The driver can start a wireless connection with the dealer in order to upload the vehicle diagnostics information to detect possible problems
Media or map download	A vehicle can start a wireless connection with the home network or a hot-spot to download maps and multimedia contents
Service announcement	Restaurants and other businesses can use a roadside unit to send promotional messages to the drivers of the vehicles that are in their communication range.

VI. CONCLUSIONS

In this work, we first present the VANET architecture. We discuss VANET research and applications. We also concentrate on VANET research approaches. Finally, we provide an appraisal of VANET research problems. This article addresses vehicular ad hoc networks from a research viewpoint, including fundamental architecture, essential research challenges, general research methodologies and result. It also serves as a complete reference for VANETs. Many VANET applications do not use conventional means of communication, but instead rely on broadcast communication and more complex information distribution systems. VANET applications fall into three categories: comfort, convenience, and safety. Safety-oriented apps seek to improve passenger safety by transmitting essential information from vehicle to vehicle (V2V) and vehicle to infrastructure (V2I). Comfort and convenience applications enhance passenger comfort and transportation efficiency. Furthermore, VANETs vary significantly from other forms of ad hoc networks, such as wireless sensor networks or mobile ad hoc networks, due to node heterogeneity and dynamics. In this work, a broad range of VANET applications are briefly presented and organized into logical groupings to provide a more succinct picture. Furthermore, node and network characteristics provide insight into the impacts on mechanism design.

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