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# Vehicular Ad-hoc Network & Exploration Plugs

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**Abstract:** Different sorts of networks can now be implemented in a variety of settings thanks to recent developments in communication technology. VANET, which stands for Vehicular Ad-Hoc Network, is a specific type of network. It falls under the category of Mobile Ad-Hoc Networks (MANET) and presents unique challenges as it enables smart communication between vehicles and infrastructure. Vehicular Ad-Hoc Network (VANET) presents a highly promising approach for the implementation of Intelligent Transport Systems (ITS), as evidenced by extensive research in this field. Since a few years ago, VANET has drawn more interest as a viable technology to improve both comfort and active and preventive safety on the road. Finding and maintaining a reliable path for data transmission is one of the primary issues facing VANET. In the midst of moving vehicles at high speeds, communication must be dependable, constant, and seamless.

***Keywords****—Vehicular Ad-Hoc Network, Intelligent Transport Domain, Communication, V2V, V2I.*

## 1. Introduction

Our roads and highways may serve as both communication and transportation platforms thanks to the confluence of telecommunications, computing, wireless, and transportation technology. In the coming years, these modifications will bring about a complete revolution in the way we access services, interact, commute, entertain ourselves, and navigate our surroundings.

In the future, the concept of ubiquitous computing is being pursued through a novel and challenging network environment known as the Vehicular Ad Hoc Network (VANET). Soon, we'll be driving around in cars that act like computer nodes outfitted with wireless connection technology, revolutionizing the way we move[1]. A new set of applications that will not only make travel safer but enjoyable are made possible by VANETs. The idea behind VANETs is rather straightforward: by integrating wireless communication and data sharing capabilities, the cars may be transformed into a network that offers services akin to those we're used to in our homes or offices.

Vehicular Ad Hoc Networks (VANETs) refer to Mobile Ad Hoc Networks (MANETs) formed dynamically among moving vehicles as the need arises. A new technology called VANET makes it possible for a variety of uses, such as intelligent transportation, infotainment, and passenger convenience. Vehicular Ad Hoc Networks (VANETs) share various characteristics with MANETs, including mobile nodes and self-organizing behavior. However, VANETs have some special qualities that make them more difficult to use, such as high node mobility, time-varying node density, frequent disconnections, a highly partitioned network, and constantly changing topology[5]. Building networks between vehicles and ensuring dependable, uninterrupted, and secure communication among the moving vehicles is a difficult task. A major problem in VANETs is routing

The academic community and business community have recently come to understand how closely working automobiles and road transport systems may increase driver safety, increase road efficiency, and lessen environmental effect. For the purpose of establishing ad hoc network connectivity, it is essential for each vehicle to be equipped with wireless communication technology.

In VANETs, vehicles possess the capability to engage in V2V (vehicle-to-vehicle) communication as well as connect to the infrastructure (V2I) to access specific services. Due to the high mobility of VANET network nodes, the network's topology undergoes constant changes. As a result, due to vehicle movements, the communication link status between two vehicles is subject to rapid variation and is prone to disconnecting. Fortunately, because it is governed by traffic networks and rules, their movement may be predicted along the route[3,4].

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The increasing popularity of vehicles as a primary mode of transportation has resulted in a significant rise in the overall vehicle population on the roads. Regrettably, the growing popularity of vehicles in recent years has given rise to various significant issues and concerns, including:

• The escalating toll of road accidents,

• The mounting costs associated with casualties and injuries,

• Growing traffic congestion woes,

• Insufficient availability of parking spaces,

• Challenges in predicting the speed of other vehicles and maintaining a safe distance.

In recent times, the Intelligent Transportation System (ITS) has attracted significant attention as one of the prominent information and communication technologies. By combining with current technology, this technology raises the level of security, dependability, and productivity in the transportation industry. Wireless communication has lately emerged as the primary technology for implementing a variety of ITS applications due to its development and growth. Wireless data connection between cars is one of the consequences that has aided in the adoption of ITS systems. The two types of communication are V2V (direct communication between vehicles) and V2I (indirect communication between cars through third-party medium, such as roadside equipment). This technology is referred to as VANET.

The key objectives of VANET can be stated as follows:

• One of the major objectives of VANET is to enable the broadcasting of warning alerts to nearby vehicles in case of collisions, obstacles, inclement weather conditions, or emergency braking situations on the road. This facilitates the dissemination of real-time information and helps to enhance road safety by providing timely warnings to drivers and enabling them to take appropriate preventive measures.

• Another important objective of VANET is to provide drivers with the most up-to-date real-time traffic information. Through VANET, vehicles can exchange information about traffic conditions, such as congestion, accidents, road closures, and alternative routes. This enables drivers to make informed decisions regarding their travel routes, helping them to avoid traffic jams and choose the most efficient and time-saving paths. By providing real-time traffic updates, VANET contributes to reducing travel time, improving overall transportation efficiency, and enhancing the driving experience for individuals on the road[7].

• VANET also aims to assist emergency vehicles in quickly maneuvering through traffic. By leveraging VANET capabilities, emergency vehicles can communicate their location, status, and urgency to other vehicles on the road. This allows nearby vehicles to recognize the presence of an emergency vehicle and make way by clearing a path or adjusting their speed. VANET enables a prioritized and efficient passage for emergency vehicles, reducing response times and potentially saving lives in critical situations.

## 2. Problem Statement

According to the World Health Organization (WHO), approximately 1.3 million people lose their lives and 50 million suffer injuries as a result of road traffic accidents each year. These staggering statistics highlight the urgent need for comprehensive road safety measures and initiatives to mitigate the significant human and societal costs associated with road accidents. In March 2021, the United Nations (UN) approved a comprehensive global plan for the Decade of Action for Road Safety 2021-2030, with the aim of reducing the alarming number of fatalities caused by traffic accidents. This mandate emphasizes the importance of addressing various aspects related to road safety management, road infrastructure, vehicle safety, and post-crash responses. As a result, there has been a heightened need for research in the field of traffic management and safety on roads, leading to significant efforts being invested in testing and evaluating different technical components of VANETs. This focus on VANETs stems from the recognition that they have the potential to contribute to innovative solutions in addressing road safety challenges and improving overall transportation safety [9,10]. The scientific community has been paying close attention to VANET technology over the past 10 years, and various vital applications for comfort and lifesaving have been developed employing this technology. Many things need to be sorted out for and by people capitalizing in order to make the applications that currently exist become useful in real life.

In VANET, the selection of an appropriate mobility model and protocol that accurately represents vehicle mobility is a significant challenge. The mobility model and protocol play a crucial role in capturing the movement patterns and behaviors of vehicles, which directly impact the performance and effectiveness of the VANET.

Accurate mobility modeling is essential for simulating realistic vehicle movements, considering factors such as speed, acceleration, deceleration, lane changes, and interaction with other vehicles. Different mobility models, such as random waypoint, Manhattan grid, or traffic-based models, have been proposed to mimic various real-world scenarios and traffic conditions. Selecting the right mobility model and protocol is crucial to accurately simulate and evaluate the performance of VANET systems. It enables researchers and developers to study and optimize various aspects, including network connectivity, data dissemination, routing, and traffic management, to enhance the overall efficiency, safety, and reliability of vehicular communication.

Indeed, in the context of vehicular traffic in VANET, there are two main levels of analysis: macroscopic and microscopic.

1. Macroscopic Level: At the macroscopic level, the focus is on understanding traffic patterns and characteristics on a large scale. This level of analysis considers aggregated data and looks at the overall behavior of traffic flow. It involves studying factors such as traffic volume, density, and average speed across a network or a specific region. Macroscopic models and simulations provide insights into traffic congestion, capacity estimation, and the overall performance of the road network.

2. Microscopic Level: The microscopic level, on the other hand, examines individual vehicles and their interactions at a granular level. It involves modeling the movement and behavior of individual vehicles, taking into account factors like acceleration, deceleration, lane-changing, and following distance. Microscopic simulations provide detailed information about vehicle trajectories, interactions, and the impact of driver behavior on traffic flow. This level of analysis is useful for studying specific scenarios, evaluating driver-assistance systems, and assessing the effectiveness of traffic management strategies.

By considering both the macroscopic and microscopic levels, researchers and practitioners can gain a comprehensive understanding of vehicular traffic in VANET. The macroscopic level provides insights into overall traffic flow and network performance, while the microscopic level offers detailed insights into individual vehicle dynamics and interactions [10-13]. Both levels are valuable for developing effective traffic management strategies, designing efficient protocols, and enhancing the safety and efficiency of vehicular communication.

The characterization of vehicle movement at both the microscopic and macroscopic levels is considered to be the primary challenge in VANET (Vehicular Ad Hoc Network). Due to the unique properties of VANET, specific networking strategies need to be defined, and their viability and performance are typically evaluated through simulation. The network's structure has a significant impact on the routing method choice. As a result, only one routing technique can accommodate the various types of ad-hoc networks.

## 3. Vehicular AD-HOC Network (VANET)

An ad hoc network refers to a collection of nodes that form a temporary network without the need for additional infrastructure or centralized control. VANETs are a rapidly emerging and notably challenging subset of Mobile Ad Hoc Networks (MANETs) [7,8]. Vehicle Ad hoc Networks, or VANETs for short, are extremely mobile wireless ad hoc networks that use outfitted automobiles as the network nodes and move these nodes relative to one another. VANETs are a distinct type of MANETs where the mobile nodes are vehicles that exhibit more regular movement by adhering to roads and traffic regulations, often traveling at high speeds in other words it is a special kind of infrastructure less wireless network where the vehicles a reacting as nodes moving across the roads or highways along a predefined traffic lane as well as it also acts as a router at the same time for forwarding of data [3].

The high mobility of network nodes in VANETs leads to a dynamic and ever-changing network topology. Consequently, the communication link status between two vehicles experiences rapid fluctuations and becomes susceptible to disconnection due to vehicle movements. Fortunately, because it is governed by traffic networks and rules, their movement may be predicted along the route. Future Intelligent Transportation Systems (ITS) are likely to include VANET as a key component.

These days, transportation, travel, and traffic are all essential components of our everyday lives. Applications and services used by end users, such as active navigation, can be supported on the backend by the collection and distribution of real-time traffic data. With the increasing number of vehicles on the road, it becomes crucial for government agencies and automakers to undertake adequate planning and development measures to effectively manage traffic and prioritize public safety. The primary concern revolves around broadcasting traffic data in a manner that is both suitable and precise, enabling real-time decision-making. Intelligent Transportation Systems (ITS) addresses various challenges related to traffic data mining and knowledge discovery, real-time traffic monitoring and surveillance, advanced highway signaling, mobility data mining, and a wide range of internet-based applications that provide entertainment and multimedia services. The effectiveness of the communication methods used by vehicles and the roadside infrastructures is a need for all of these ITS technologies[12]. An essential part of ITS is vehicular communication (VC), in which vehicles exchange information with each other and/or with roadside infrastructure, evaluate the information they receive, and make decisions based on their analysis.

**Intelligent Transport System (ITS)**

Around the world, the development of VANET has sparked considerable interest, particularly in Japan's ITS (Intelligent Transportation System) initiative. For information to be broadcast to the vehicular network in Intelligent Transportation Systems, each vehicle takes on the roles of sender, receiver, and router. In this system, vehicles broadcast information to the transportation authority, which utilizes it to ensure the smooth and safe flow of traffic. Hardware that allows for precise position information, such as GPS, must be installed in vehicles.

The communication setup in ITS encompasses inter-vehicle, vehicle-to-roadside, and routing-based communications. All of these configurations necessitate precise, accurate, and up-to-date surrounding information. Achieving this relies on the utilization of an accurate positioning system and well-designed communication protocols for efficient information exchange [8, 9]. For effective communication between vehicles and Road Side Units (RSUs), vehicles need to be equipped with a radio interface or On Board Unit (OBU). This facilitates the establishment of short-range wireless ad hoc networks, enabling seamless communication between vehicles and RSUs. Applications for Intelligent Transportation Systems (ITS) encompass various functionalities, including cooperative traffic monitoring, flow control, blind crossing assistance, and collision avoidance.

A. **Inter Vehicle Communication**

This type of communication is commonly referred to as Vehicle-to-Vehicle (V2V) communication or pure ad hoc networking. In this group, there is no infrastructure to support vehicle-to-vehicle communication. Any useful data gathered by a vehicle's sensors can be transmitted to nearby vehicles.

Inter-vehicle communication supports multi-hop multicasting or broadcasting to a number of receivers over a number of hops. ITS is typically more interested in what is happening on the road ahead than the one behind it. In inter-vehicle communications, two message forwarding techniques are commonly employed: naive broadcasting and clever broadcasting.

Figure 1 illustrates the concept of inter-vehicle communication.

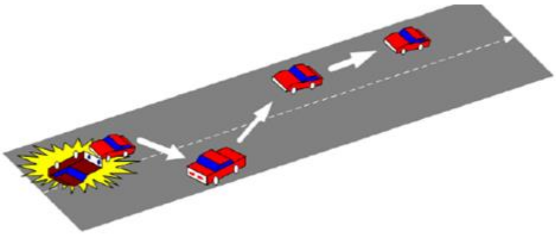

**Fig 1:** Inter-Vehicle Communication [6]

B. **Vehicle-To-Roadside Communication**

This category is also referred to as Vehicle-to-Infrastructure (V2I) communication. In V2I communication, vehicles have the capability to connect to the Internet and support vehicular applications through the utilization of cellular gateways and wireless local area network access points. In this kind of communication, all equipped vehicles get a broadcast message from the roadside unit, which is how vehicle communication is carried out. A sample quantity of bandwidth is made available between communicating parties and RSU with this kind of arrangement. In vehicle-to-roadside communication, the roadside unit is given the maximum load necessary for proper communication. When it detects that a vehicle is exceeding the desired speed limit, the system intervenes by controlling the vehicle's speed and broadcasting a warning message. This message can be delivered through auditory or visual means, alerting the driver to decelerate. Figure 2 illustrates vehicle-to-roadside communication, where Road Side Units (RSUs) transmit broadcast messages to all equipped vehicles in the vicinity[14].

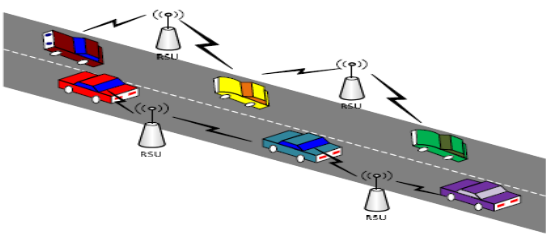


**Fig 2:** Vehicle-to-Roadside Unit Communication [6]

**C. Routing-Based Communication**

The routing-based communication configuration in Intelligent Transportation Systems (ITS) typically employs a multi-hop unicast method. This method enables the transmission of messages between vehicles or between vehicles and Road Side Units (RSUs) through multiple intermediate hops. The car uses a multi-hop transmission technique to convey the message till it reaches the target vehicle. In routing-based communication within VANET, the intended vehicle becomes the recipient of a unicast message sent by the sending vehicle.

Figure 3 illustrates routing-based communication in VANET, where vehicle A transmits a message to vehicle C utilizing routing protocols.

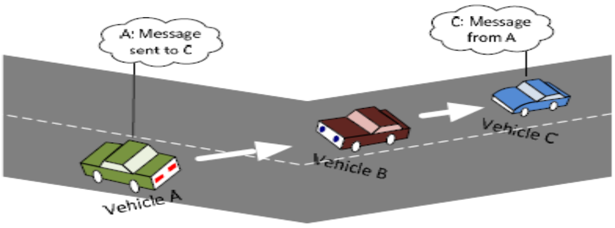


**Fig 3:** Routing-Based Communication [6]

## 4. Vanet Architecture

For communication between vehicles or between a vehicle and a Road Side Unit (RSU), a wireless technology called WAVE (Wireless Access in Vehicular Environments) is utilized. WAVE enables reliable and efficient wireless communication in VANETs. Safety applications leveraging this type of communication provide drivers and travelers with access to a diverse array of information, enhancing road safety and driving convenience. The primary system components involved in this communication setup are the AU (Application Unit), OBU (On Board Unit), and RSU (Road Side Unit) [2-5]. These components work together to facilitate effective communication and enable the deployment of various safety-related applications. In most cases, the RSU functions as a host for service-providing applications, while the OBU acts as a peer device that utilizes these services. The RSU serves as a central hub for delivering various services, and the OBU interacts with the RSU to access and utilize those services based on the specific requirements of the vehicle or the driver. In the context of the communication setup, the device hosting the application is commonly referred to as the provider, while the device utilizing the application is referred to as the user. The application itself can be located either in the RSU or the OBU, depending on the specific deployment scenario and requirements. In the vehicular communication system, each vehicle is equipped with an On Board Unit (OBU) and a set of sensors to collect and process data. The processed data is then wirelessly transmitted as messages to other vehicles or Road Side Units (RSUs). The RSU, in addition to its role in vehicular communication, can also establish connections to the internet or other servers. This connectivity enables Application Units (AUs) from multiple vehicles to connect to the internet and access various online services [ 8-13].

### C. **On-Board Unit (OBU)**

OBUs, which are WAVE (Wireless Access in Vehicular Environments) devices, are typically installed on vehicles and used for information exchange with RSUs or other OBUs. An OBU consists of various components, including:

- RCP (Resource Command Processor): It manages the overall operation of the OBU and handles resource allocation and task execution.
- Short-range wireless communication network device: This component utilizes IEEE 802.11p radio technology for communication within the vehicular network.
- User interface: It provides a means for users or drivers to interact with the OBU, such as through displays or buttons.
- Custom interface: This interface allows the OBU to connect with other OBUs for data exchange.
- Read/write memory: The OBU uses this memory to store and retrieve information as needed.

Moreover, the OBU provides communication services to the Application Unit (AU) and transmits data over the network to other OBUs. The primary functions of the OBU include wireless radio access, ad hoc and geographical routing, network congestion control, reliable message transfer, data security, and IP mobility.

### D. **Application Unit (AU)**

The AU is a device installed within the vehicle that leverages the communication capabilities of the OBU to establish communication with the applications provided by the service provider. It enables the vehicle occupants to interact with and access various applications and services offered by the provider through the OBU's connectivity and networking capabilities. The AU and OBU can be integrated into a single physical unit and interconnected using either wired or wireless methods. This integration allows for a more compact and streamlined setup, ensuring seamless communication between the AU and the OBU within the vehicle. The connection between the AU and OBU can be established through wired interfaces or wireless protocols, depending on the specific implementation and design considerations.

The OBU serves as the central component responsible for handling all networking and mobility tasks within the vehicle communication system. It acts as the intermediary between the AU and the network infrastructure, serving as the only point of contact between the AU and the external network. The OBU manages the communication protocols, connectivity, and data exchange between the AU and the network, ensuring that the AU can access the desired applications and services seamlessly.

E. **Roadside Unit (RU)**

The Road Side Unit (RSU) is a WAVE (Wireless Access in Vehicular Environments) device that is typically mounted on the side of the road or strategically placed in specific locations such as intersections or near parking spaces. The RSU is equipped with a network device designed for specialized short-range connections using IEEE 802.11p radio technology. Additionally, the RSU may have additional network devices to facilitate internal network communication within the RSU itself. This allows the RSU to establish communication links with nearby vehicles and OBUs, enabling data exchange and providing various services to the vehicles in its vicinity. According to the C.C. Communication Consortium, the main functions and procedures associated with the Road Side Unit (RSU) include:

- **Broadcast Communication:** The RSU broadcasts messages to nearby vehicles, providing important traffic information, road conditions, or alerts.
- **Information Collection:** The RSU collects data from vehicles, sensors, and other sources to gather information about traffic patterns, congestion, and other relevant parameters.
- **Data Processing:** The RSU processes the collected data to derive meaningful insights and generate useful information for traffic management and control purposes.
- **Traffic Control:** The RSU plays a vital role in controlling traffic by providing signals, coordinating traffic flow, and implementing intelligent traffic management strategies.
- **Service Provisioning:** The RSU hosts various services and applications, such as real-time navigation assistance, emergency notifications, parking availability information, and more, to enhance the driving experience and ensure safety.
- **Connectivity:** The RSU establishes connectivity with the internet or other servers, allowing for access to external data sources, cloud-based services, and remote management capabilities.
- **Security and Authentication:** The RSU implements security measures to protect the integrity and confidentiality of the transmitted data, ensuring secure communication between vehicles and the RSU.
- **Maintenance and Monitoring:** The RSU requires regular maintenance and monitoring to ensure its proper functioning, including software updates, hardware checks, and fault detection.

These functions and procedures collectively enable the RSU to serve as a crucial component in the intelligent transportation system, facilitating efficient traffic management, enhanced safety, and improved overall driving experience

- Redistributing the information to other On Board Units (OBUs) and forwarding it to other Road Side Units (RSUs) allows for an extended communication range within the ad hoc network. By relaying the information through multiple OBUs and RSUs, the network can effectively transmit data to a wider range of vehicles. This redistribution mechanism enhances the reach and coverage of the ad hoc network, enabling efficient communication and dissemination of information among vehicles and infrastructure components. (Figure 4).

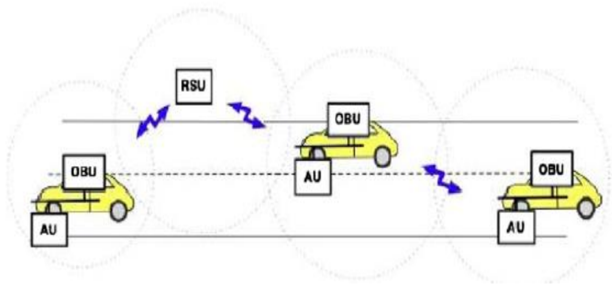


**Fig 4:** RSU Extends the Range of the Ad Hoc Network by forwarding the Data of OBUs

- Infrastructure to Vehicle (I2V) communication is utilized to enable safety applications such as low bridge alerts, accident warnings, and work zone notifications. In this mode of communication, the infrastructure, represented by Road Side Units (RSUs), serves as an information source to vehicles. The RSUs transmit relevant safety information, such as the height of a low bridge, the presence of an accident, or the existence of a work zone, to vehicles in the vicinity. This helps drivers to be aware of potential hazards and make informed decisions while driving. By leveraging I2V communication, the infrastructure plays a vital role in enhancing road safety and providing timely alerts and notifications to vehicles on the road. (Figure 5).

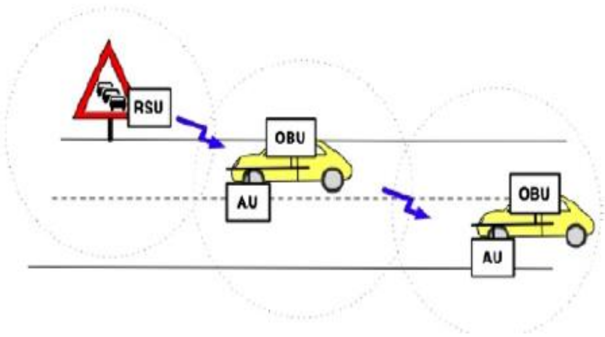


**Fig 5:** RSU Works as Information Source (Running Safety Application)

- One of the functions of Road Side Units (RSUs) in vehicular communication systems is to provide internet connectivity to On Board Units (OBUs) in vehicles. RSUs can serve as access points or gateways that enable OBUs to connect to the internet. This connectivity allows OBUs to access a wide range of online services, applications, and information sources. By providing internet connectivity, RSUs enhance the capabilities of OBUs, enabling features such as real-time traffic updates, navigation assistance, multimedia services, and communication with external servers or cloud-based platforms. This connectivity not only improves the driving experience for vehicle occupants but also opens up possibilities for various internet-based applications and services within the vehicular environment. (Figure 6)

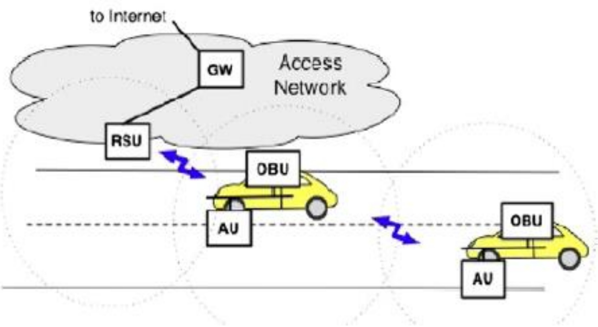


**Fig 6:** RSU Provides Internet Connectivity to OBUs

## 5. Vanet Communication Domain

The communication between vehicles and the RSU, as well as the broader infrastructure, can be classified into three distinct domains: [1]:

F. **In-Vehicle Domain**

The In-Vehicle Domain refers to the internal communication and components within a vehicle. It encompasses various systems and devices that are present inside the vehicle and facilitate communication and functionality for the occupants. The In-Vehicle Domain comprises an On Board Unit (OBU) and one or more Application Units (AUs). It is possible to find both the OBU and AU integrated into the same device, and their connection can be established through either wired or wireless means[15].

The OBU plays a crucial role in facilitating the execution of various applications offered by the application provider within the vehicle. It leverages its communication capabilities to establish a communication link with the Application Unit (AU) and enable the seamless transmission of data and information.

By offering a communication link to the AU, the OBU allows the AU to access and utilize the communication infrastructure provided by the OBU. This communication link serves as a pathway for the AU to interact with the OBU and leverage its connectivity features, network interfaces, and data processing capabilities.

G. **Ad-Hoc Domain**

The Ad-Hoc Domain in Vehicular Ad Hoc Networks (VANETs) refers to the dynamic and self-configuring network formed by vehicles equipped with On Board Units (OBUs). In this domain, vehicles establish ad hoc connections with neighboring vehicles to enable direct communication and information exchange.

The Ad-Hoc Domain allows vehicles to form temporary networks without relying on any fixed infrastructure or centralized control. It enables vehicles to communicate with each other, share relevant data, and collaborate on various tasks such as cooperative sensing, collision avoidance, traffic management, and information dissemination.

The ad hoc domain in Vehicular Ad Hoc Networks (VANETs) is formed by vehicles equipped with On Board Units (OBUs) and a roadside station known as the Road Side Unit (RSU). This domain plays a critical role in enabling ad hoc communication and information exchange within the VANET. Together, the vehicles with OBUs and the RSU create the ad hoc domain, forming a self-organizing and self-configuring network. This domain enables vehicles to communicate with each other and the infrastructure without relying on a centralized control system or fixed infrastructure.

H. **Infrastructural Domain**

The infrastructural domain in Vehicular Ad Hoc Networks (VANETs) refers to the centralized infrastructure that supports the communication and management of vehicles within the network. It includes various components and entities that provide services, connectivity, and control to vehicles and play a crucial role in the overall functioning of VANETs.

The infrastructural domain provides the necessary infrastructure, connectivity, and control to support the operation of VANETs. It enables vehicles to access critical information, communicate with external entities, and receive services that enhance road safety, traffic efficiency, and overall user experience. The components within the infrastructural domain work together to ensure seamless communication and efficient management of the vehicular network.

The RSU can link to the infrastructure networks or the Internet, giving the OBU access to the infrastructure network. In this scenario, the Application Units (AUs) can be registered with the On-Board Unit (OBU) to establish connections with internet-based hosts. The OBU acts as a gateway for the AUs, enabling them to access internet-based services and applications. This registration process allows the AUs to utilize the communication capabilities of the OBU to connect to external hosts and exchange data [17, 18].

## 6. Conclusion

Wireless technologies in the VANET field are generating a lot of interest. Using the VANET concept, automobiles can communicate while travelling at high speeds on the highways. This has made it possible to create new user applications as well as traffic engineering, traffic management, and the distribution of emergency information to prevent dangerous circumstances. Modelling emergency situations on the roadways, such as accidents, is made easier with the integration of network and traffic simulators at runtime. The goal of VANET is to create a strong network between mobile vehicles so that they can communicate with one another for human safety. With all these features, modern automobiles are able to monitor and share the road, traffic, and weather conditions with other vehicles, which makes the ride safer by preventing road accidents.

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