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VEHICULAR AD-HOC NETWORKS (VANETs)-AN OVERVIEW OF DEVELOPMENT AND INNOVATIONS

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Abstract **:** Recently VANETs (**Vehicular Ad-Hoc Network)** have came-up to turn concentration of Researchers in the field of wireless and mobile communication and travelling ideas automatic vehicle from now on. Vehicular ad hoc network is one most interesting research area due to broadcasting vehicle information on TMS, Lowbudget, high sensing fidelity, creating new application for road safety .VANET is the type networks that are created from the idea of build up network of cars for alerts and warning for critical situation.With help VANET network drivers get alert for quick decisions by predicting and helping the drivers.This paper outlines VANET definition, its architecture and routing protocols from research point of view and future research direction of VANET are provided in the end of paper.

Keywords- Vehicular ad-hoc networks, Vanet architecture, Vanet communication types, Vanet routing protocols, application, and Vanet's challenges faced, Vanet innovations areas.

I. INTRODUCTION

VANET'S main aim to provide Road safety to people from accidents because 60% human error in driving met accidents on roads. To avoid these critical situations with the help of VANETs safety application that provide continue Broadcast information about critical situation and weather updates. Vanet plays an important role in our life for safe driving, smart navigation and emergency and entertainment applications. In the last few years ago, mobile communication has changed our life styles allowing us to share information, anywhere at any time. At the present time cars and other private vehicles are increased daily that can causes accidents on the roads.VANET defined as an intelligent component of transport system as vehicle is able to communicate with each other as well as roadside unit. Which are located at critical points of the road for example Intersection and construction sites.VANET can be used to enhance Traffic management, reduce the congestion in network with help of ITS (Intelligent Transportation system). VANET is same as MANET (Mobile Ad-hoc Network) in which vehicles equipped with wireless and without any support from an existing internet infrastructure or any other fixed network station. MANET is peer to peer multiple wireless networks in which packets are transmitted vehicle to vehicle.

II. VANET'S ARCHITECTURE

The Architecture of a vehicular ad-hoc network (VANET) provides a facility for communication between vehicle to vehicle (V2V) and Vehicle to infrastructure (V2I) for improving road safety. VANET is divided into three main system components are:

2.1 On board unit (OBU)

An OBU is WAVE device assembled for used exchanging information with RSUs .It contain Resource command processor (RCP) and resource involve a read/write memory used to store and to recover from storage information.OBU is installed in vehicle and other devices to sense the vehicle around and collect traffic data with help of sensors. OBU based on IEEE 802.11P radio technology for wireless communications to fulfil the interaction requirements with all the external elements.

2.2 Application unit (AU)

The application unit is the tool outfitted inside the automobile that uses the application given for one householder utilizing the conversation capabilities of the OBU. The AU may be a committed device for security application and devices like PDA (personal digital assistant), Laptop, GPS, Smart phones to run the internet. The AU can be connected to the OBU With wire and wireless connection (Wi-Fi). The AU takes responsibility for all mobility and networking functions.

2.3 Road side unit (RSU)

The RSU is wave gadget usually fixed near the road side or near parking spaces. Road Side Unit connected to the internet and provides the guidance to the user about traffic problems, road accidents so that user knows about situation to take decisions accordingly.

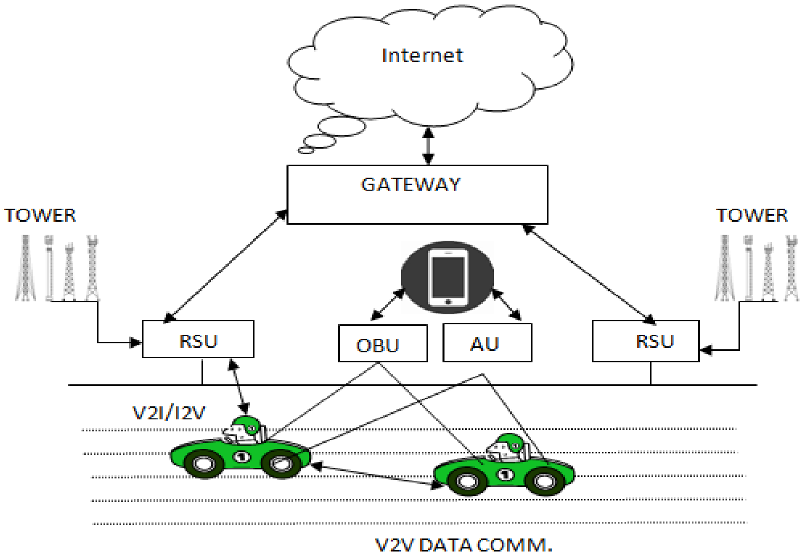

Figure: 1 Vanet Architecture

III. VANET COMMUNICATION TYPES

Recent advancements in vehicular Ad-Hoc Networks (VANETs) are transforming the landscape of intelligent transportation system (ITS). These networks enable seamless communication between vehicles and vehicles (V2V) and infrastructure to infrastructure (I2I), enhancing road safety and traffic management. Key developments include the implementation of sophisticated routing protocols that optimize data transmission and reduce latency, ensuring timely information exchange among vehicle. Moreover, security remains a critical focus, with researches developing robust frameworks to protect against potential cyber threats. The integration of artificial intelligence (AI) and machine learning (ML) is also gaining interaction, allowing for real- time data analysis and decision- making, which is essential for autonomous driving technologies. Additionally, ongoing research is addressing challenges such as network scalability, reliability, and the efficient handling of dynamic vehicular environments. These efforts are crucial for accommodating the increasing number of connected vehicles on the road. As VANETs continue to evolve, they promise to enhance traffic flow, reduce congestion and ultimately contribute to safer and more efficient transportation system. The future of VANETs looks promising, with the potential to revolutionize how we navigate and interact with our roadways. The communication relies on technologies like Dedicated Short-Range Communication (DSRC) and cellular networks, which provides low latency and high reliability. However, challenges such as network congestion, security vulnerabilities, and privacy concerns need to be addressed. Future advancements, including the integration of 5G technology and machine learning algorithms, promise to enhance data transmission efficiency and support innovative applications, paving the way for smarter and safer transportation system.

Data communication in Vehicular Ad-Hoc Networks (VANETs) involves the exchange of information between vehicles and infrastructure to enhance road safety and traffic management. This communication can be categorized into Vehicle-to-Vehicle (V2V) and Vehicle –to-infrastructure (V2I) interaction, enabling vehicles to share real-time data about traffic conditions, accidents, and hazards. The use of dedicated short-range communications (DSRC) and cellular networks facilitates this data exchange, ensuring low latency and high reliability. Challenges such as networks scalability, security, and data privacy must be addressed to optimize communication efficiency. As VANETs evolve, integrating advanced technologies like 5G and machine learning will further improve data transmission and support innovative applications, ultimately contributing to smarter transportation systems. Data communication in Vehicular Ad-Hoc Networks (VANETs) is crucial for enhancing road safety and traffic efficiency. It primarily involves two types of communication: Vehicle-to-Vehicle (V2V) and Vehicle-to-Infrastructure (V2I). V2V communication allows vehicle to share critical information such as speed, location, and potential hazards, while V2I communication connects vehicle to roadside units for traffic management and real-time update. The different types of communication are as follows:

3.1 Vehicle to Vehicle Communication

It refers to inter vehicle communication. Vehicle or a group of vehicle connect with one another and communicate like point to point architecture. It proves to be very helpful for cooperative driving.

3.2 Vehicle to Infrastructure Communication

The number of base stations positioned in close proximity with a fixed infrastructure to the highway is necessary to provide the facility of uploading and downloading of data from the vehicles.

3.3 Hybrid communication

In VANETs network is divided into group that are self managed group of vehicles.TDMA use multi-point communication connection between the clusters.

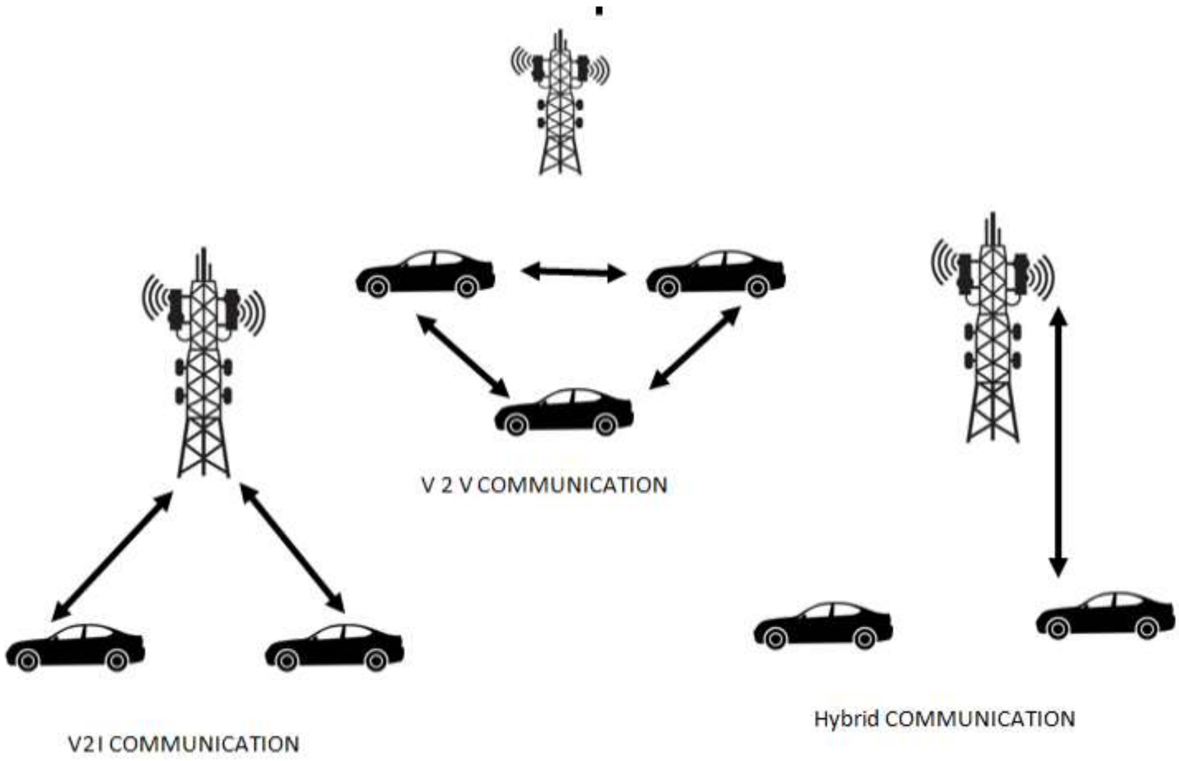

Figure: 2 Vanet communication types

IV. VANET ROUTING PROTOCOLS

VANET routing protocols are essential for facilitating communication between vehicles in a dynamic environment. Routing protocols help to collect and share the information between the vehicles requires some rules through which transmission can take place in an organized way. The data exchange between nodes in a VANET done with routing protocols. These protocols can be categorized into five routing protocols are:

4.1 Topology based routing protocols

These routing protocols use links that exists in the network to perform packet forwarding. They are further divided into proactive and Reactive. Proactive protocol used optimized link state routing protocol (OLSR) for continuously update routes. OLSR has less average end to end delay therefore it is used for application that needs minimum delay. In this uses dynamic topology to capable of adapting to changes in the network topology quickly. Which makes it suitable for uses dynamic environments such as MANETS (Mobile ad-hoc networks). Reactive Protocols are used to set about doing establish routes ondemand .Reactive protocols have less overhead than protocols but they can put oneself in the place of another network topology change more moderately. In this we use AODV (Ad-hoc on-demand distance vector routing).Hybrid protocol combine features of both to optimize performance. Each of these types is with distinct mechanisms for route discovery and maintenance. The choice of protocol impacts factors like latency, reliability and scalability, which are crucial for applications such as traffic management and safety alerts. Challenges include handling high mobility, ensuring security against attacks and managing network congestion. Ongoing research aims to enhance these protocols to support the growing demands of intelligent transportation systems. VANET routing protocols play a critical role in enabling efficient communication among vehicles and infrastructure in real time scenarios.

4.2 Position based routing protocols

Position based routing consists of class of routing algorithm.thet share the property of using geographic positioning information in order to select the next forwarding hops. The packet is send without any map knowledge to the one hop to neighbour, which is nearest to destination. Such as GPSR, utilize geographical information to make routing decisions. This is further divided into three types:

4.2.1 Position Based greedy V2V protocols

In greedy strategy and intermediate node in the route forward message to the closet neighbour in the direction of next destination. Greedy approach requires that intermediate node should possessed position of itself, position of its neighbour and destination position.Such as GPSR (Greedy Perimeter Stateless Routing) in wireless networks, GPCR, CAR, and DIR.

4.2.2 Delay Tolerant Protocols

In city where vehicle are densely packed locating a node to carry a message is not a problem because highway but in rural highway situation or in cities at night fewer vehicles are running and establishing end to end route difficult. So that situation provides spare networks. Ex. MOVE, VADD, SADV

4.2.3 Traffic flow oriented routing (TFOR)

Aim to enhance performance by considering traffic density and vehicle direction, ultimately contributing to safer and more efficient transportation system.

4.3 Cluster based routing protocols

Cluster based routing is preferred in cluster. A group of nodes identifies themselves to be a part of cluster and a node is designated as cluster head will broadcast the packet to cluster. The various cluster based routing protocols are COIN and LORA_CBF.

4.4 Geo-cast routing protocol

Geo cast routing is basically a location based multicast routing .its objective is to deliver the packet from source node to all other nodes within a specified geographical area. the various Geo cast routing protocols are IVG,DTMAC/TRPM,DV-CAST.

4.5 Broadcast routing protocols

Broadcast routing is frequently used in VANET for sharing traffic, weather and emergency, road conditions among vehicles and delivering advertisements and announcement. The various types are BROADCOMM, UMB, and VTRADE.

V. APPLICATION

The four major classes of applications possible in VANET are intelligent transport Application, safety Application, comfort application, for TMS (Transportation Management System) and commercial oriented. They are work for driver comfort and also reduce the congestion in network.

5.1 Safety Applications

Safety application will monitor the surrounding road, approaching vehicle, surface and curves of road. give 360* degree awareness to driver and show the warning alerts time to time.eg: STOP CRASH ALERT!,DO NOT PASS WARNING,RAIL CROSSING VIOLATION WARNING ,BLIND SPOT WARNING.

5.2 Comfort Application

Parking place management, peer to peer application, distributed games, Electronic toll collection, Route Diversions.

5.3 Intelligent Transport Application

Traffic Monitoring, traffic management, vehicle tracking, notification services.

5.4 Commercial Applications

These are classified into remote vehicle Personalization/Diagnostics internet Access, Digital map Downloading, Real time video relay, value-added advertisement.

VI. VANET'S CHALLENGES FACED

Vehicular Ad-Hoc networks (VANETs) face several significant challenges that hinder theirfull potential. One of the primary issues is the highMobility of vehicles, which can lead to frequent disconnection andNetwork fragmentation. This dynamic environment complicates routingProtocols, making it difficult to maintain stable communication links.Security is another critical challenge, as VANETs are susceptible tovarious cyber threats, including data tampering and unauthorized Access. Ensuring the integrity and confidentiality of communication between vehicles and infrastructures is paramount to prevent malicious Attacks that could put at risks safety. Additionally, the need for quality of service (QOS) is essential; balancing these necessities while directing the limited Resources convenient in a vehicular network is a complex task. Moreover, the integration of diverse communication technologiesPoses interoperability challenges, as vehicles from different Manufacturers may use different protocols .Addressing these Challenges requires on-going research and innovation in areas such asLightweight block chain solutions , advanced routing techniques, andRobust security frameworks . As the number of connected vehicles continues to grow, overcoming these obstacles will be crucial for the Successful deployment of VANETs. Recent advancements in vehicular Ad- hoc networks (VANETs) are accompanied by several challenges that need to be addressed for their effective implementation.

6.1 High Mobility and Network Stability

The rapid movement of vehicles leads to frequent changes in networkTopology, resulting in disconnections and instability. This dynamicNature complicates the development of reliable routing protocols,making it difficult to maintain consistent communication.

6.2 Security Vulnerabilities

VANETs are particularly vulnerable to cyber threats, including dataBreaches and unauthorized access. Ensuring secure communicationbetween vehicles and infrastructure is critical to prevent maliciousAttacks that could compromise safety and privacy.

6.3 Quality of Service (QoS) Requirements

Different application within VANETs has varying demands for Bandwidth and latency. Meeting these QoS requirements while Managing limited network resources presents significant challenges, as failure to do so can lead to degraded performance for critical applications.

6.4 Interoperability issues

The integration of various communication technologies can create interoperability challenges, especially when vehicles from different manufacturers utilize different protocols. This lack of standardization can hinder seamless communication across the network.

6.5 Broadcasting collision issue

MAC Protocol based on TDMA. In this frequency channel multi-hop used distributed scheme. Broadcasting with distributed scheme two type collisions occurs: access collision and merging collision. Access collision: when two or more vehicle need same slot to access network then one vehicle not connected and wait for network. Merging collision: When two vehicles use same network frequency channel on RSU. To resolve this issue TDMA use TMAC/TRPM free slot frame that provide network to all vehicles without interfering.

VII. VANET INNOVATIONS AREA'S

Recent innovations in vehicular Ad-Hoc Networks (VANETSs) focus on enhancing communication efficiency and security. One of the important achievements is the integration of a machine learning algorithm that optimizes routing protocols by predicting vehicle movement patterns and improving the reliability of data transmission. Additionally, the development of lightweight block chain technology is being explored to enhance security, ensuring data integrity and preventing unauthorized access. Another notable innovation is implementation of 5Gtechnology, which offers higher offers higher bandwidth and lower latency, facilitating real-time communication between vehicles and infrastructure. This is crucial for applications like autonomous driving and traffic management systems. Furthermore, researchers are working on advanced simulation tools that follow for the testing of various scenarios in VANETs, helping to refine protocols and improve overall network performance. These innovations collectively aim to create a more robust, secure and efficient vehicular communication environment, paving the way for Ad hoc networks (VANETs) are transforming the landscape of intelligent transportation systems. One of key innovations is the use of Graph neural Networks (GNNs), which enhance traffic forecasting and resource scheduling by effectively analyzing complex, non-linear data structures. This allows for more accurate predictions of traffic flow and vehicle demand, optimizing urban mobility. Moreover, the integration of 5Gtechnologies is revolutionizing VANETs by providing higher data rates and lower latency, essential for real-time applications such as collision avoidance and autonomous driving. This connectivity enables vehicle to communicate seamlessly with each other and with infrastructure, improving overall safety and efficiency. Additionally the development of advanced routing protocols that adapt to the dynamic nature of vehicular networks is crucial.

VIII. CONCLUSION

The future of VANETs looks promising, with the potential to revolutionize how we navigate and interact with our roadways.VANET is a promising wireless communication technology for improving highway safety and information services.in future many challenges ahead, the good impact of VANETs on traffic management must be shown. This paper outlines the idea of what a VANET is all about.One of key innovations is the use of Graph neural Networks (GNNs), which enhance traffic forecasting and resource scheduling by effectively analysing complex, non-linear data structures.

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