Exploring VANETs and their applications with Blockchain.

Sowmya K S[1], Shivani A[2] , Shree Charan M L[3] and Swetha Swaminathan[4]

[1,2,3 & 4] B.M.S College of Engineering, Bengaluru, Karnataka, India

shivani1812a@gmail.com

Abstract. As the digitization of cities and the proliferation of automobiles continue, Vehicular Ad-Hoc Networks (VANETs) have emerged as a prominent solution to enhance road safety and traffic management. VANETs enable vehicles to establish communication channels with each other (V2V) and with infrastructure nodes (V2I), facilitating real-time information exchange for applications like collision avoidance, traffic management, and multimedia delivery. This paper offers an in-depth analysis of popular VANET protocols, including 802.11p, WAVE IP, DSRC, and WSMP, to provide a comprehensive understanding of their functionalities within the VANET ecosystem. Through simulation studies involving simultaneous broadcast and unicast systems between nodes and Roadside Units (RSUs), as well as WSMP-based neighbor systems, we investigate their effectiveness in realistic scenarios. Ensuring the reliability and security of VANETs remains a substantial challenge. To address this, the paper explores the potential advantages of integrating VANETs with Blockchain technology. By leveraging Blockchain's inherent immutability and decentralized architecture, VANETs can be fortified against malicious attacks and unauthorized access, thereby enhancing the overall system security. Furthermore, this paper investigates the vast potential of utilizing data obtained from VANETs. We examine various applications that can effectively leverage this data to make informed decisions and improve transportation systems. A noteworthy example involves the incorporation of Machine Learning models, where data from VANETs is processed through a Blockchain network to obtain valuable predictions for actionable insights. This demonstrates how VANETs can contribute significantly to intelligent transportation systems and urban planning.

Keywords: V2V, V2I, IEEE 802.11p, WSMP, WAVE, IEEE 1609.4-2013, Blockchain.

1 Introduction

The rapid advancements in self-driving cars and the ongoing digital transformation of cities have paved the way for the proliferation of Vehicular Ad Hoc Networks. VANETs represent a unique paradigm in networking, where each vehicle acts as an autonomous node in a mobile ad hoc network as illustrated in Fig. 1 obtained from paper [6]. The inherent characteristics of VANETs, such as frequent node mobility and dynamic topology changes, pose significant challenges for achieving efficient and reliable communication. We delve into the realm of VANETs, focusing on the critical role played by communication protocols in facilitating effective data exchange among vehicles and infrastructure.

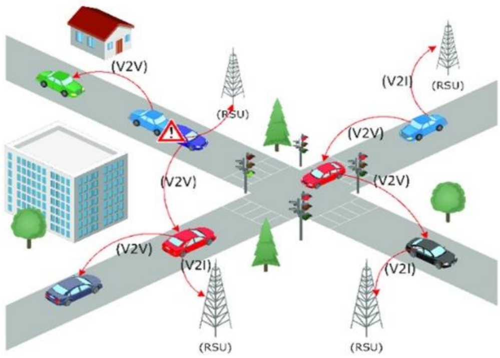


Fig. 1. Architecture of VANETs

To address the specific requirements of VANETs, a plethora of communication protocols has been developed. These protocols are designed to handle the high node mobility, intermittent connectivity, and bandwidth limitations that are characteristic of vehicular environments. We discuss the key features and functionalities of prominent VANET communication protocols, including IEEE 802.11p/WAVE (Wireless Access in Vehicular Environments) and Dedicated Short-Range Communications (DSRC).

As VANETs generate vast amounts of real-time data, leveraging this data for various applications holds immense potential. Blockchain technology offers a decentralised and tamper-resistant framework that can enhance the security, privacy, and reliability of data collection in VANETs [7]. We examine the integration of blockchain in VANETs to enable secure and trustworthy data collection applications. Through the use of smart contracts and data authentication, blockchain can facilitate trustworthy data sharing, traffic management, and predictive analytics in VANET environments. The data collected from VANETs holds immense potential for gaining valuable insights and making informed predictions. By leveraging Machine Learning techniques, patterns and trends within the data can be analysed to optimise traffic management, predict traffic congestion, and enhance overall transportation efficiency in VANETs.

2 Related Work

Existing works in VANETs and their applications encompass a wide range of research and development efforts aimed at leveraging vehicular ad hoc networks to enhance road safety, traffic efficiency, and user experience. Paper [1] highlights the importance of efficient routing protocols in VANETs due to their fast-changing topology and dynamic nature. The study evaluates the efficacy of AODV, OLSR, DSDV, and DSR protocols using NS3 as a simulator and SUMO for vehicle movement generation. Metrics such as power consumption, packet distribution factor, average performance, and maximum end-to-end delay are considered. This research underscores the need for routing protocols that can cope with high velocity, frequent dissociations, and evolving topologies. Paper [2] focuses on the IEEE WAVE standard, considered a promising technology for VANETs, aiming to ensure interoperability and robust safety communications in a vehicular environment. This study reviews the latest released version of the IEEE WAVE standard and presents the status of each standard in the IEEE 1609 series. It emphasizes the significance of IEEE 1609.4 for multi-channel operation and highlights the new features of the WAVE Media Access Control (MAC) layer. Furthermore, it discusses the services and protocols offered by IEEE 1609.3 as a network service standard. Paper [3] explores the vast potential of VANET applications in the automotive industry. Collaborative efforts by consortia like VSC, CAMP, and VII, along with major vehicle manufacturers, have focused on developing pre-competitive safety technologies and real-world implementations. The paper categorizes various VANET applications, highlighting their features and benefits. The significance lies in the ability of on-board units (OBUs) in vehicles to form networks with roadside units (RSUs) without additional infrastructure, paving the way for innovative and life-changing applications. Paper [4] emphasizes the recent advances in wireless communication technologies and their impact on VANET research. VANETs, with their vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) communications, have attracted attention in areas such as vehicle collision warning and traffic information dissemination. Government, industry, and academia collaboration in ongoing research projects signifies the importance of VANETs as a key field of wireless communication. Paper [5] delves into the challenges posed by the dynamic and intermittent connected topology of VANETs, influencing data communication and application design. The survey identifies the protocol stack used in VANETs and compares common protocols in the literature. Moreover, it presents various categories of VANET applications, each catering to specific quality-of-service (QoS) requirements. The paper highlights open research problems that demand innovative solutions to optimize data communication in VANETs.

3 Background

Some of the well-known wireless communication technologies used primarily in vehicular environments, especially for Intelligent Transportation Systems (ITS) are WSMP, WAVE, 802.11p, and IEEE 1609.4-2013. They play a crucial role in enabling communication between vehicles and infrastructure to improve road safety and traffic efficiency.

3.1 WAVE (Wireless Access in Vehicular Environments)

WAVE is a set of standards and protocols defined by the IEEE 802.11 Working Group for wireless communication in vehicular environments. It is based on the IEEE 802.11 standard, which is commonly known as Wi-Fi. WAVE extends the capabilities of 802.11 to address the specific requirements of vehicular communication, such as fast handovers, high mobility support, and prioritised message delivery. The key components of the WAVE architecture include 802.11p, WSMP and IEEE 1609 family. The WAVE Protocol Stack is demonstrated in Fig 2 obtained from paper [8].

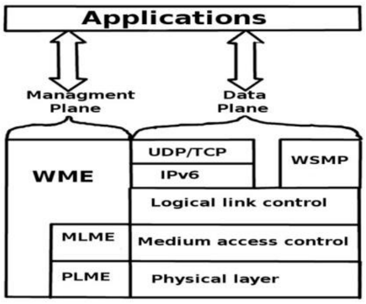


Fig. 2. WAVE Protocol Stack

3.2 WSMP (Wireless Short Message Protocol)

WSMP is a communication protocol designed specifically for vehicular ad hoc networks (VANETs). It is part of the WAVE (Wireless Access in Vehicular Environments) architecture and is defined in IEEE 1609.3 standard. WSMP operates at the data link layer of the OSI model and is designed to handle short, high-priority messages, typically used for safety-critical applications. These messages are often referred to as Basic Safety Messages (BSMs) and contain important information, such as vehicle position, speed, acceleration, and heading. The primary goal of WSMP is to ensure the timely and reliable delivery of these safety messages between vehicles and between vehicles and roadside infrastructure.

3.3 802.11p

IEEE 802.11p is a specific amendment to the 802.11 standard, developed to support Wireless Access in Vehicular Environments (WAVE). It operates in the 5.9 GHz band. 802.11p is designed to provide low-latency communication for safety-critical applications in vehicular networks, such as collision avoidance and emergency braking.

3.4 IEEE 1609.4-2013

IEEE 1609.4-2013 is a standard that defines the channel scheduling protocol for Wireless Access in Vehicular Environments (WAVE) communication systems. The channel scheduling protocol is used to manage and allocate resources in the vehicular communication network to ensure efficient and reliable communication among vehicles. The different channel access modes for transmitting data between vehicles are illustrated in Fig 3. The various modes are -

- Continuous: In the continuous channel access mode, a vehicle continuously occupies a specific time slot for transmitting its data.
- Alternating: In the alternating channel access mode, vehicles take turns transmitting data in predefined time slots.
- Immediate: The immediate channel access mode allows a vehicle to immediately access the channel for data transmission as soon as it becomes available.
- Extended: The extended channel access mode provides a longer duration for data transmission compared to other modes.

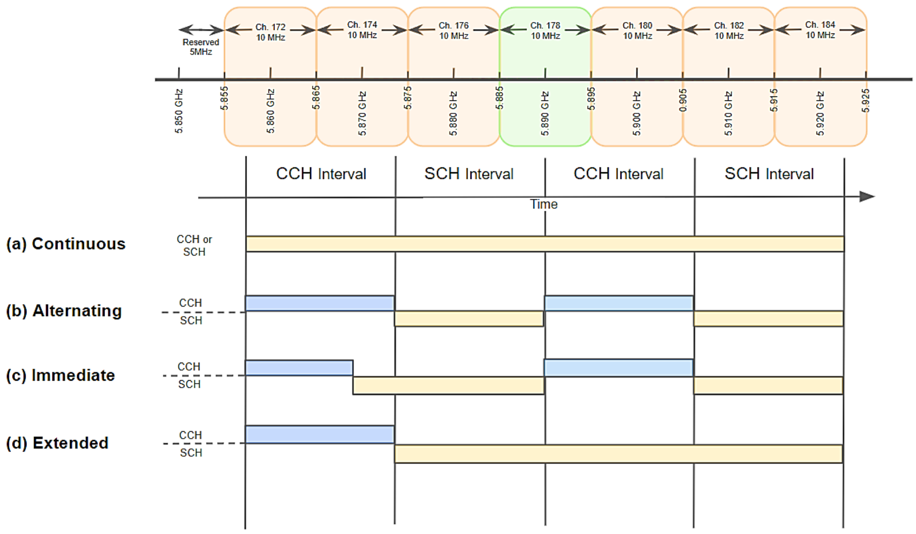


Fig. 3. Various scheduling protocols under IEEE 1609.4-2013

4 Simulation and Results

There are mainly 2 simulations demonstrated for the purpose of this paper - Simulation of a simultaneous broadcast and unicast system between nodes and RSU (V2I communication) and Simulation of WSMP based neighbours' system (V2V communication). Along with that, a blockchain based application of VANET's Traffic Flow Prediction has also been developed to demonstrate one of the potential applications of the vehicular data collected from VANETs.

4.1 Algorithm 1: Simulation of a simultaneous broadcast and unicast system between nodes and RSU.

- Input: m_nodes are initialised, with m_rsu being no of RSU nodes, and m_veh being no of vehicles.
- Input: Vehicle nodes are given a constant velocity. Odd vehicle nodes are given velocity v1 and even vehicle nodes a velocity of v2.
- Input: RSU nodes are given a velocity of 0 and a position such that they start at 200.0,0,0 and are separated by 500 x axis units.
- Input: Initialise an unordered_map <int, vehicleNode> in RSUTable.

Operations performed by RSU:

1. for each m_broadcast_interval do
2. Send broadcast signals.
3. Listen to both unicast and broadcast messages on the physical layer (using ns3 MonitorSnifferRx).
   (1) On receiving an Acknowledge message from a vehicle node, check if RSUTable has a record of the vehicle node.
   (2) If record exists, update last_beacon time, else add it to the table.
   (3) Regularly traverse the RSU Table, and remove all vehicleNodes where last_beacon is older than a certain threshold.
   (4) end for

Operations performed by Vehicle Nodes:

1. Initialise rsu_mac to broadcast address and rsu_beacon to 0.
2. Listen to broadcast messages on the physical layer (using ns3 MonitorSnifferRx).
3. On receiving broadcast from RSU, check if rsu_mac is equal to broadcast address.
4. If yes, set rsu_mac, rsu_beacon and schedule acknowledgeRsu() to run regularly, else update rsu_beacon.
5. Regularly check if the rsu_beacon is older than the threshold.
6. If yes, set rsu_mac to broadcast, and stop acknowledgeRsu()

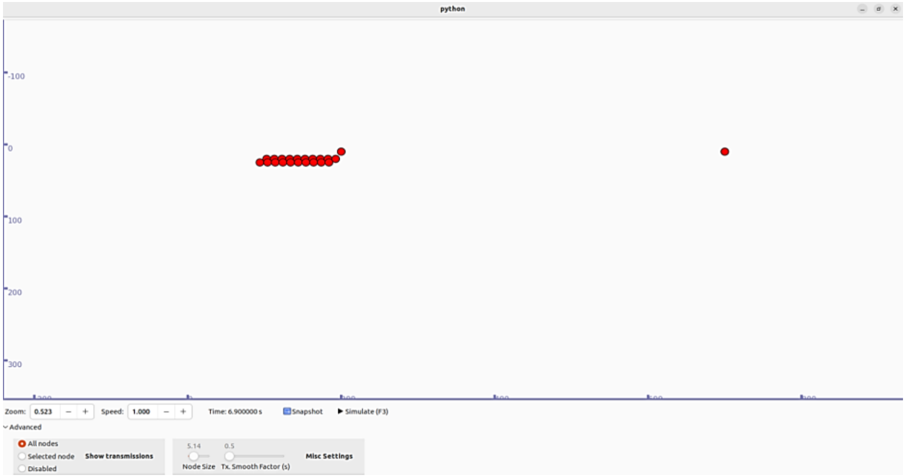


Fig. 4. Simulation of vehicle movements and RSU

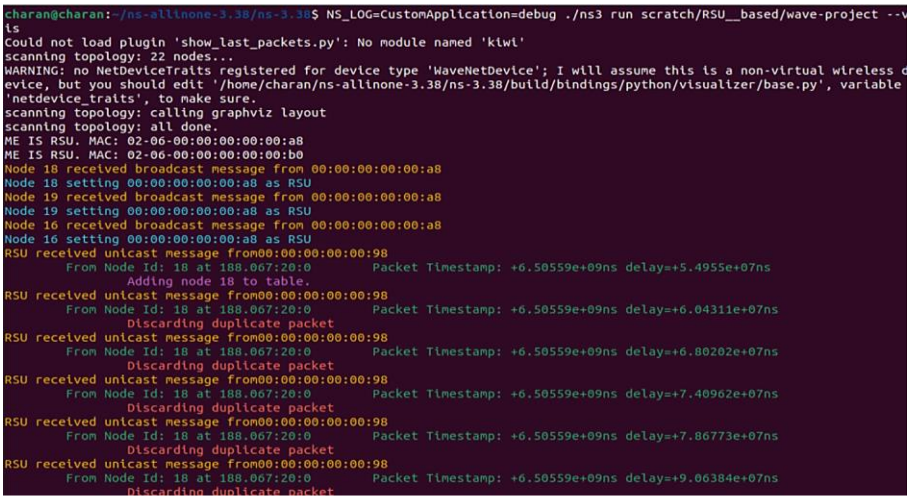


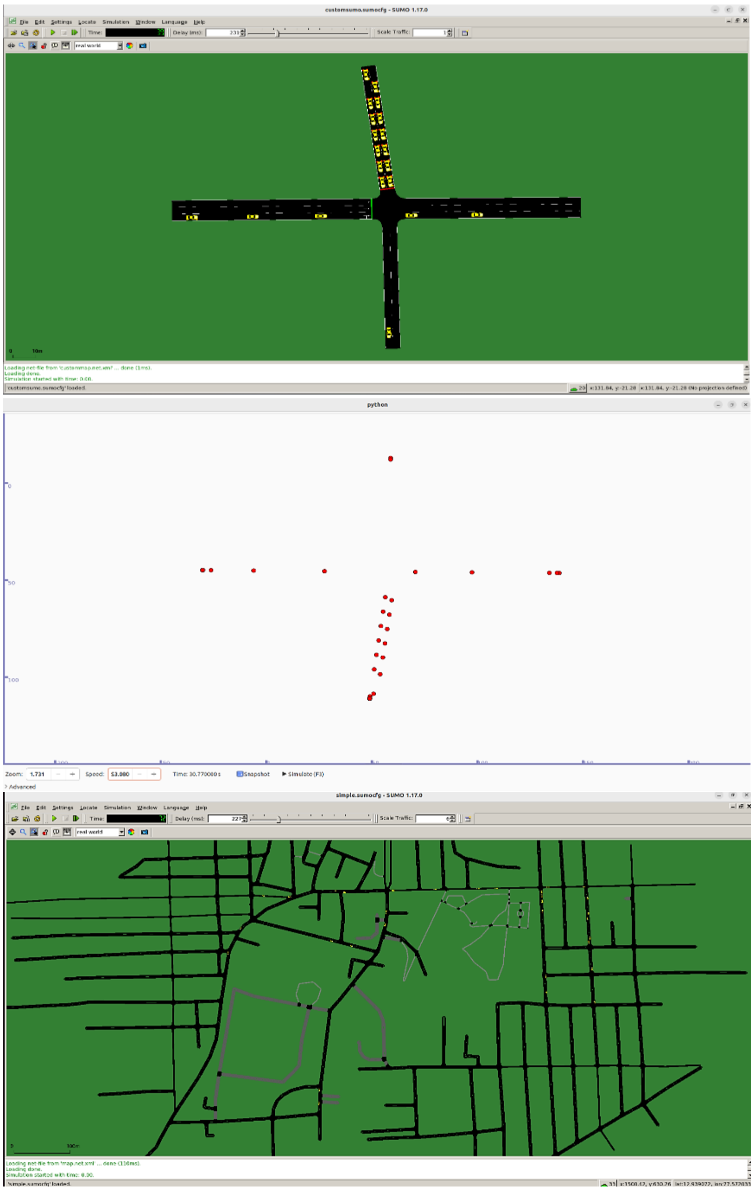
Fig. 5. Background logging information of nodes getting registered and deregistered from the RSU

4.2 Algorithm 2: Simulation of WSMP based neighbors' system.

- Input: 2 maps are generated using SUMO: a simple highway junction with a traffic stop and a real world map around B.M.S College of Engineering.
- Input: Sumo tools are used to generate ns2tracefiles which can be used to define the nodes in a ns3 simulation.
- Input: Nodes are read from ns2tracefiles which have mobility simulated using SUMO.

Operations performed by Neighboring Nodes:

1. Vehicle nodes are constantly sending broadcast signals of their existence.
2. Vehicle nodes upon receiving WSMP signals either add them to the list (vector) or update the last beacon time.
3. Vehicle nodes regularly remove all entries from the list where the last beacon is above a certain threshold.
4. Vehicles are constantly aware of their neighbouring vehicles.



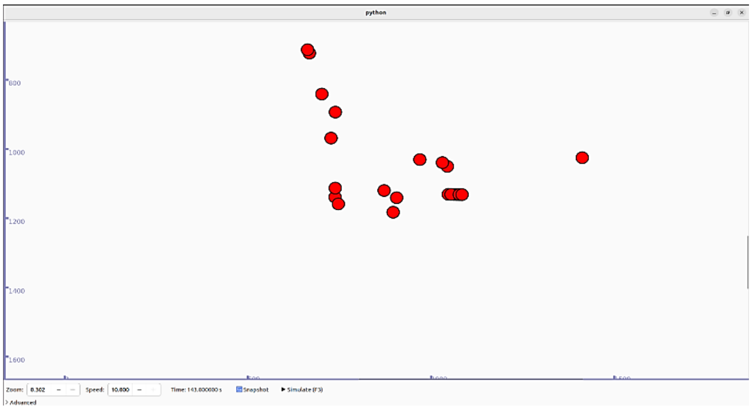


Fig. 6. Demonstration of WSMP on simple highway junction and Basavanagudi Map

Through these simulations, we have clearly demonstrated the V2V and V2I communications effectively. There were some challenges that were encountered during the implementation of these simulations, such as packet loss during channel switching, which need to be investigated more in detail.

5 Applications

Now that the various possible types of communications have been explored, we also look at what applications can be built around the data obtained from VANETs. While there is a plethora of possible applications, we try to demonstrate one useful application that can be made using traffic data i.e., the traffic flow prediction application. Prediction of traffic flow is a beneficial concept to approximate how much traffic there would be at a given time in each place. We take the vehicular data collected at an RSU level and store that information in a local Ethereum blockchain called Ganache for more secure storage of the data. Later, it is retrieved from the blockchain and passed to a Random Forest Regressor model to train and test the model, which is later used to predict the traffic flow at any given timestamp in each location and speed.

While this is just one application that has been implemented, there are several other applications which can be developed in the future using vehicular data obtained (like speed. location, timestamp etc.). The applications of VANETs in the automotive industry can be classified into four categories: safety-oriented, commercial-oriented, convenience-oriented, and productive applications [3]. Safety applications include real-time traffic monitoring, co-operative message transfer, and emergency alerts. Commercial applications include toll collection, parking management, and fleet management. Convenience applications include infotainment, internet access, and navigation. Productive applications include vehicle diagnostics, remote vehicle monitoring, and remote software updates.

6 Conclusion

Vehicular Ad Hoc Networks (VANETs) have proven to be effective in enhancing road safety, traffic management, and providing value-added services. VANETs facilitate real-time information exchange, enabling drivers to receive alerts about potential dangers and improving overall road safety. In this paper, we have explored and analyzed the current communication protocols used in vehicular ad hoc networks (VANETs) in order to determine how well they enable interactions between nodes in a model network. We have also investigated novel applications of blockchain technology and machine learning models in VANET, to analyze the vast amounts of traffic data gathered from these networks.

Future enhancements should focus on standardization and interoperability to ensure seamless communication between different vehicles and infrastructure providers. Robust security mechanisms and privacy protection are vital to safeguard sensitive information exchanged in VANETs. Efficient routing algorithms, congestion control, and resource management techniques are necessary to handle scalability challenges and ensure reliable communication.

References

1. Jan, Maria, et al: VANET routing Protocols: Implementation and Analysis Using NS3 and SUMO, International Journal 10.3 (2021).
2. Ahmed, S. A., S. H. Ariffin, and Norsheila Fisal.: Overview of wireless access in vehicular environment (WAVE) protocols and standards, environment 7.8 (2013).
3. Lee, Michael, and Travis Atkison. Vanet applications: Past, present, and future, Vehicular Communications, 28 (2021): 100310.
4. E. C. Eze, S. Zhang and E. Liu, "Vehicular ad hoc networks (VANETs): Current state, challenges, potentials and way forward," 2014 20th International Conference on Automation and Computing, Cranfield, UK, 2014, pp. 176-181, doi: 10.1109/IConAC.2014.6935482.
5. Felipe Domingos da Cunha, Azzedine Boukerche, Leandro Villas, Aline Carneiro Viana, Antonio A. F. Loureiro. Data Communication in VANETs: A Survey, Challenges and Applications. [Research Report] RR-8498, INRIA Saclay; INRIA. 2014. ⟨hal-00981126v4⟩
6. Patil, Rashmi, and Rekha Patil: IJCNC 05 Cross Layer Based Congestion Free Route selection In Vehicular Ad Hoc Networks
7. Dwivedi, Sanjeev Kumar, et al.: Blockchain-based vehicular ad-hoc networks: A comprehensive survey, Ad Hoc Networks (2022): 102980.
8. Profentzas, Christos. "Studying Routing Issues in VANETs by Using NS-3." (2012).