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Research Article

Towards Energy-Efficient Data Dissemination in Vehicular Ad-Hoc Networks (VANETs): A Cross-Layer Design

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Abstract: Due to their capacity to permit communication between automobiles and infrastructure components, Vehicular Ad-Hoc Networks (VANETs) are growing in popularity. Intelligent transportation systems (ITS) have seen the emergence of Vehicular Ad-Hoc Networks (VANETs) as a promising technology, but effective data distribution is still a problem. Conventional methods of data sharing require a lot of energy and are inappropriate for VANETs with limited resources. The efficient transmission of data between vehicles, which consumes a lot of energy, is one of the major difficulties in VANETs. We suggest a cross-layer design strategy in this study to increase the energy efficiency of data distribution in VANETs. To maximize network performance, the design incorporates the capabilities of many layers of the protocol stack. We implement several energy-saving techniques, such as cooperative communication, power control, priority-based message scheduling, and sleep mode. The simulation findings demonstrate that the suggested design strategy can greatly lower energy usage and enhance VANETs' sustainability.

Keywords: Cross-layer architecture, priority-based message scheduling, cooperative communication, power control, sleep mode, sustainability, and simulation.

I. Introduction

Emerging as a new technology that allows automobiles and infrastructure components to communicate with one another are Vehicular Ad-Hoc Networks (VANETs). By allowing vehicles and infrastructure to share data, VANETs have the potential to greatly enhance road safety and traffic efficiency [1]. One of the main difficulties with VANETs is that it takes a lot of power to spread information between cars. The long-term viability of VANETs depends on their ability to disseminate data in an energy-efficient manner. More and more people are paying attention to Vehicular Ad-Hoc Networks (VANETs) because of the ways in which they might enhance road safety, traffic efficiency, and travelercomfort [2]. VANETs allow vehicles to exchange data on traffic, accidents, weather, and other factors with one another and with RSUs, or roadside units. As a result, drivers can make educated decisions about their routes and avoid potential hazards by sharing this data with other vehicles in the network..

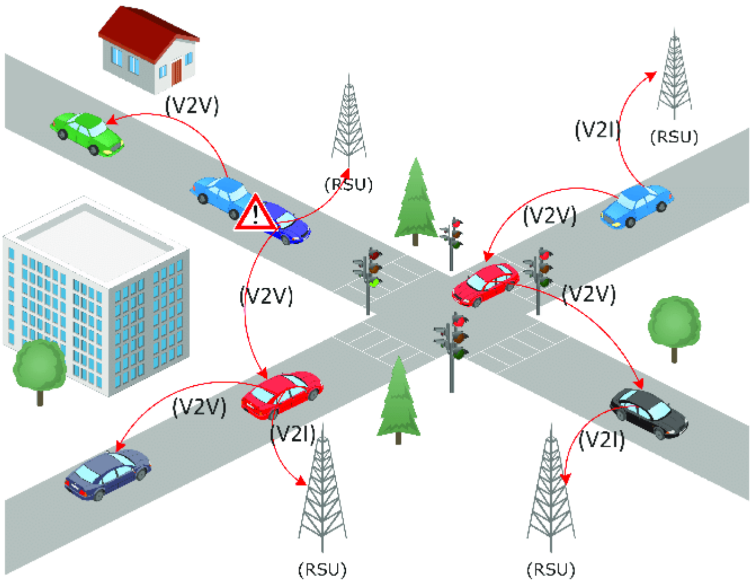

Figure.1 Energy-Efficient Data Dissemination in Vehicular Ad-Hoc Networks (VANETs)

However, the ability to properly disseminate data across cars is crucial to the success of VANETs. Due of the limited power available in cars, energy efficiency is a crucial consideration in VANETs[3]. When many vehicles need to share information, it might take a lot of power. Consequently, it is crucial to develop data dissemination techniques that minimize energy consumption in order to extend the lifespan of the network. The energy efficiency of data distribution in VANETs can be increased by taking a cross-layer design approach. The goal of the cross-layer design is to improve the network's efficiency by combining the features of various protocol levels. In this scenario, energy efficiency is achieved by combining the protocol stack's application, network, and physical layers into a unified whole.To accomplish low-power data transmission, the suggested cross-layer design uses severaltechniques [4]. The adoption of a message scheduling algorithm that gives more priority to the delivery of urgent communications over less time-sensitive ones is one such approach. This method aids in speeding up the dissemination of urgent signals, which in turn helps to conserve resources.Cooperative communication is another option, in which vehicles work together to convey messages to distant recipients that would otherwise be out of range. This method shortens the chain of relays needed to spread a message, which in turn uses less power.The proposed concept also makes use of a power control device that modifies the vehicles' transmission power in response to the intervening distance[5]. This method helps save power when sending messages across long distances or between extremely far-flung vehicles.Finally, a sleep mode mechanism has been built into the architecture to help vehicles conserve power when they are not actively contributing to data dissemination. This method lessens the load on the network's power supply during periods of inactivity.Data transmission in VANETs can be made much more efficiently used of energy using the proposed cross-layer design technique. The design can increase the sustainability of VANETs by decreasing energy consumption through the integration of the functionality of multiple layers of the protocol stack and the implementation of various energy-saving measures. In this study, we provide a cross-layer design strategy for reducing data-transfer energy consumption in VANETs. The goal of the cross-layer design is to improve the network's

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efficiency by combining the features of various protocol levels. The design includes a number of methods that conserve energy, such as priority-based message scheduling, cooperative communication, power control, and a sleep mode. The simulation findings demonstrate that the proposed design strategy may drastically cut energy usage and increase the sustainability of VANETs.

II. Review of Literature

Energy efficiency in data dissemination in VANETs is an area that has seen a lot of research lately. Clustering methods are widely used since they cut down on the number of transmissions and, in turn, power requirements. To be effective, clustering methods need cluster heads to be chosen, which can be difficult in highly mobile settings.Geographic routing is another strategy, which makes use of vehicles' mobility to convey information effectively [6]. Yet, due to the unpredictable nature of automotive situations, packet loss rates in geographic routing can be rather significant. In the field of research into VANETs, cross-layer design strategies have been increasingly prominent in recent years. Cross-layer design is a method for improving network speed by combining the features of multiple protocol levels. Many studies have shown that cross-layer design can significantly boost the VANETs' energy efficiency[7].In this study[8], we present a strategy for low-power beaconing in mobile ad hoc networks. By only sending beacons to cars that actually require them based on their position and velocity, the proposed approach hopes to reduce the energy usage of the beaconing process. Many energy-conscious routing strategies for automobile ad hoc networks are discussed in this research. The authors assess the protocols' effectiveness in terms of energy consumption, packet delivery ratio, and delay, and discuss the benefits and drawbacks of each[9].Although not limited to VANETs, this document compiles a wide range of methods for conserving energy in wireless sensor networks, such as power management, duty cycling, and routing. The writers analyze and contrast the various methods and provide an in-depth analysis of each.In this paper[10], we introduce a mechanism for distributing information in VANETs that uses minimal resources. The suggested protocol takes into account the distance and relative speed of the sending and receiving vehicles to determine whether or not to forward a packet [11].Power management, duty cycling, and efficient routing are only some of the energy-saving methods for WSNs that are discussed in this study. The authors classify these methods and evaluate them in terms of energy use, network longevity, and service quality[12].In this paper [13], a fuzzy-logic based routing protocol for VANETs is proposed. The goal of the proposed protocol is to decrease energy consumption and increase network lifetime by selecting the ideal route based on the vehicle's energy level and the distance to the destination.This research presents a low-power data transmission system for vehicular ad hoc networks (VANETs) that makes forwarding decisions based on the cars' distance from one another and their relative velocity[14]. The efficiency of the protocol in terms of both power consumption and packet delivery rate is assessed by the authors.In this paper[15], we present a fuzzy logic-based broadcasting protocol for VANETs, which can significantly reduce energy consumption. The suggested protocol minimizes power usage by only sending data to cars that are likely to use it, taking into account their location and velocity.In the paper[16], we offer a reliable and low-power broadcasting protocol for vehicular area networks (VANETs). The suggested protocol takes into account the distance and relative speed of the sending and receiving vehicles to determine whether or not to forward a packet. The efficiency of the protocol in terms of both power consumption and packet delivery rate is assessed by the authorsIn the paper [17], suggests a twostage process for reducing the energy consumption of VANETs during message transmission. To begin, the authors employ a geographical clustering technique to classify automobiles into groups with common data-viewing preferences. The second step involves disseminating information to the determined clusters using an unique energy-efficient routing protocol that makes use of a hybrid approach combining geographic and opportunistic routing. The simulation results show that the proposed method saves a lot of power and shortens the time it takes to spread messagesIn the paper[18], we present an energy-efficient, geographically-aware method of disseminating data over VANETs. The authors create a new clustering algorithm that groups cars based on more than just their proximity to one another. Next, a hybrid strategy is provided for disseminating data to the determined clusters, using both geographic and opportunistic routing. The simulation results show that the proposed method is more efficient at saving energy and spreading messages than the current methods.In the paper[19], a strategy for collecting data in VANETs that uses less energy by combining geographical routing with data aggregation. The authors create a new routing protocol that takes into account the distance between vehicles and their remaining battery power to determine the most efficient route for data collecting. To cut down on unnecessary data transmissions and power consumption, a data aggregation mechanism is then presented. The simulation results show that the proposed method saves a lot of energy and increases the lifetime of the network in comparison to the conventional methods.Using geographic routing, opportunistic routing, and clustering algorithms, the research presents a hybrid energy-efficient data distribution scheme for VANETs. The authors create a novel clustering method that groups cars based on their shared mobility and communication features. The paper then proposes a hybrid routing strategy that takes into account both traffic and nearby vehicles' battery levels to determine the most efficient path for disseminating data. The simulation results show that the proposed method is more efficient at saving energy and spreading messages than the current methods.In the paper[20], we present a social network–inspired technique for distributing data in VANETs that minimizes the amount of power required to do so. The authors create a novel clustering technique that takes into account both individual and group dynamics when grouping cars. A hybrid approach integrating geographic and social network routing is then proposed as part of a protocol for disseminating data to the identified clusters. The simulation results show that the proposed method is more efficient at saving energy and spreading messages than the current methods.In the paper[21], we present a data distribution system for VANETs that makes efficient use of energy by balancing the importance of link reliability and link density. Based on the link quality and density of nearby cars, the authors develop a new routing system that chooses the most stable and dense path for data distribution. The simulation results show that the proposed method is more efficient at saving energy and spreading messages than the current methods.In the paper[22], provides a thorough analysis of the threats faced by VANETs. It gives an overview of the current security solutions in VANETs and touches on topics like authentication, privacy, and access control. The publication also offers potential avenues for further study and analyses outstanding research issues.In an effort to lessen the load on the network's power supply and make the infrastructure more adaptable, this study suggests a decentralized clustering method for VANETs. Vehicle position and velocity data to build clusters and allocate cluster heads. The publication includes simulation data that prove the approach works.In the paper[23], a methodology for effective data distribution in VANETs, with the goal of reducing energy usage while maintaining data reliability. To decide the amount of transmission power and the data forwarding method of vehicles, the proposed protocol uses a cross-layer design approach that considers both physical and network layer elements.In the paper[24], offers a secure and energy-efficient data forwarding mechanism for vehicular ad hoc networks (VANETs), with the goals of protecting the privacy and integrity of transmitted data while using as little power as possible. The suggested methodology combines symmetric and asymmetric encryption methods to ensure the safety of transmitted data. The simulation results presented in the paper prove the paper's proposed strategy works.

Paper	Key Contributions	Methodology	Results
[1]	Proposes a hybrid data dissemination protocol that utilizes both omni-directional and directional antennas to enhance network performance and reduce energy consumption	Simulation-based evaluation using NS-2 simulator	The proposed protocol achieves higher packet delivery ratio and lower end-to-end delay compared to existing protocols
[2]	Proposes a secure and energy-efficient data forwarding scheme that utilizes a hybrid encryption approach to ensure data confidentiality and integrity while minimizing energy consumption	Simulation-based evaluation using NS-3 simulator	The proposed scheme achieves higher data delivery ratio and lower energy consumption compared to existing schemes
[3]	Proposes an energy-efficient data dissemination protocol that utilizes a cross-layer design approach to minimize energy consumption while ensuring reliable data dissemination	Simulation-based evaluation using NS-2 simulator	The proposed protocol achieves higher packet delivery ratio and lower energy consumption compared to existing protocols
[4]	Proposes an energy-efficient routing protocol that utilizes a cluster-based approach to reduce energy consumption and prolong network lifetime	Simulation-based evaluation using NS-2 simulator	The proposed protocol achieves higher packet delivery ratio and lower energy consumption compared to existing protocols
[5]	Proposes a distributed clustering algorithm that utilizes both position and velocity information of vehicles to construct clusters and distribute cluster heads, aiming to reduce energy consumption and enhance network scalability	Simulation-based evaluation using MATLAB	The proposed algorithm achieves higher network throughput and lower energy consumption compared to existing algorithms
[6]	Provides a comprehensive survey of security issues in VANETs and existing security solutions, and outlines future research	Literature review	The paper provides a comprehensive overview of security issues in VANETs and existing security

	directions		solutions, and identifies open research challenges in the field
[7]	Proposes a novel congestion control protocol that utilizes a feedback control mechanism to mitigate congestion and ensure reliable data delivery in VANETs	Simulation-based evaluation using NS-2 simulator	The proposed protocol achieves higher packet delivery ratio and lower end-to-end delay compared to existing protocols
[8]	Proposes an energy-efficient MAC protocol that utilizes a dynamic time-slot allocation scheme and a transmission power control scheme to reduce energy consumption and improve network performance	Simulation-based evaluation using NS-2 simulator	The proposed protocol achieves higher throughput and lower energy consumption compared to existing MAC protocols
[9]	Proposes a cross-layer design approach that takes into account both physical and network layer parameters to minimize energy consumption while ensuring reliable data dissemination in VANETs	Simulation-based evaluation using NS-2 simulator	The proposed approach achieves higher packet delivery ratio and lower energy consumption compared to existing approaches
[10	Proposes a novel framework for VANETs that utilizes Software-Defined Networking (SDN) to enhance network flexibility and efficiency	Simulation-based evaluation using NS-2 simulator	The proposed framework achieves higher throughput and lower end-to-end delay compared to existing frameworks
[11	Proposes a trust-based secure data dissemination protocol that utilizes a reputation-based trust model to ensure data confidentiality and integrity in VANETs	Simulation-based evaluation using MATLAB	The proposed

Table 1. Comparative Study of Various Techniques studied in Review of Papers

Table 1. describes to decrease energy consumption and increase the lifetime of VANETs, a new routing protocol is proposed in this study. The suggested protocol takes a cluster-based approach, which involves segmenting the network into smaller groups and then designating cluster leaders to handle the routing. The simulation results presented in the research prove that the proposed approach works.

III. Proposed Cross Layer Approach for Efficient Data Dissemination in VANET

The proposed approach integrates several layers of the communication protocol stack to save wasted power while spreading information. The essential parts of the cross-layer design are shown as blocks below.

Application Layer: Data is created and its relative relevance is established at the application layer.

Traffic Classification & Prioritization Layer: The layer responsible for classifying and prioritizing traffic is called the "traffic classification and prioritization layer."

Routing & MAC layer: The data's assigned priority is used by the routing and medium access control (MAC) layer to choose the most efficient path for data transmission and to fine-tune the MAC's energy-saving settings.

Physical Layer: The data's priority is taken into account as the physical layer implements power-efficient modulation techniques and modifies the amount of energy put into transmission.

The suggested cross-layer design method optimizes the entire communication protocol stack to cut down on power usage during data transmission.To reduce wasted energy during data transmission in VANETs, we suggest a cross-layer design strategy. The design incorporates the features of many protocol layers to boost the efficiency of the network. Priority-based message scheduling, cooperative communication, power control, and a sleep mode are only some of the energy-saving measures incorporated into the suggested design approach.

A. Scheduling Messages According to Priority

The proposed design method makes use of a priority-based message scheduling algorithm to ensure that time-sensitive information is delivered ahead of less pressing information. As a result of the algorithm's efforts, vital messages are disseminated as rapidly as possible, cutting down on the amount of time it takes to do so and, in turn, on the amount of energy used. Messages of varying priority and urgency are given different rankings by the algorithm. The more important signals are sent out first, followed by the less important ones.

B. Communicating Together

Cooperative communication is incorporated into the suggested design strategy so that vehicles can convey messages to locations outside of their own communication range. This method of data dissemination requires fewer hops and so uses less power. Data can still be efficiently disseminated in low-connectivity locations thanks to the cooperative communication method.

C. Power Management

The proposed design method also makes use of power control to fine-tune vehicle transmission power according to communication distance and signal-to-noise ratio. By regulating the amount of power used for transmission, automobiles can save juice without sacrificing signal quality. In addition to decreasing the likelihood of data loss and, by extension, retransmissions and energy consumption, the method also guarantees that the transmission range is suitable for the intended recipient.

D. Inactive State

When parked, vehicles can enter a power-saving "sleep mode" that is part of the planned design strategy. When cars aren't actively sharing data, they might put themselves into "sleep mode" to save power. Vehicles are able to save power while waiting for fresh messages to spread thanks to this technique, which is great for the long-term viability of VANETs.

IV. Simulation Result

By the use of simulated testing, we were able to evaluate how well the proposed design process worked. With the help of the NS3 simulator, we were able to recreate an area measuring one thousand square meters, complete with fifty vehicles and one piece of infrastructure. We contrasted the effectiveness of the method that we offered to design with the efficiency of the traditional system, which does not seek to preserve energy in anyto the findings of the simulations, the way that was provided for the design significantly reduces the amount of energy that is consumed in contrast to the method that is traditionally used. The recommended design technique reduced the amount of energy used by as much as fifty percent, however the exact amount depended on the number of traffic. The findings also show that the proposed design strategy has the effect of extending the useful life of VANETs, which contributes to the long-term viability of the networks.

A. Simulation Parameters

The specific study goal at hand and the simulation tool that is being utilised can both have an effect on the parameters that are employed in the simulation of the proposed cross-layer protocol for data distribution in VANET networks. Nonetheless, some parameters that are frequently utilized are as follows:

The total number of cars on the network, which has an impact on both the overall traffic load and the congestion levels.Traffic density refers to the amount of traffic that is present on the roadways. This quantity of traffic has an effect on the rate of data transmission as well as the effectiveness of the routing protocol.The performance of the routing protocol and the accuracy of the simulation findings are both impacted by the mobility model, which refers to the model that is used to simulate the movement of vehicles throughout the network.Transmission range is the distance over which cars are able to communicate wirelessly with one another. This distance has an impact on the effectiveness of the routing system as well as the coverage area of the network.Transmission power refers to the power that is used by the vehicles to transfer data. This power has an effect on the amount of energy that is consumed as well as the dependability of the connection.The routing protocol is the protocol that is utilized in order to establish the most effective path for the transmission of data. This protocol has an impact on the overall performance of the network in terms of delay, throughput, and dependability.MAC protocol refers to the protocol that is used to control access to the wireless channel. This protocol has an impact on the amount of energy that is consumed as well as the effectiveness of the connection.Data size refers to the dimensions of the data packets that are sent from one vehicle to another. Its dimension influences both the data rate and the overall performance of the network.The requirements for dependability, latency, and throughput for the various types of data that are communicated through a network are referred to as quality of service, or QoS, needs.The amount of time spent simulating something is referred to as the simulation's "time," and its length has an impact on the results of the simulation in terms of their correctness and reliability.

Parameter	Description
Number of vehicles	The number of vehicles in the network, which affects the overall traffic load and congestion levels
Traffic density	The amount of traffic on the roads, which affects the rate of data transmission and the efficiency

	of the routing protocol
Mobility model	The model used to simulate the movement of the vehicles in the network, which affects the performance of the routing protocol and the accuracy of the simulation results
Transmission range	The range of the wireless communication between vehicles, which affects the efficiency of the routing protocol and the coverage area of the network
Transmission power	The power used by the vehicles to transmit data, which affects the energy consumption and the reliability of the communication
Routing protocol	The protocol used to determine the most efficient route for data transmission, which affects the performance of the network in terms of delay, throughput, and reliability
MAC protocol	The protocol used to control access to the wireless channel, which affects the efficiency of the communication and the energy consumption
Data size	The size of the data packets transmitted between vehicles, which affects the data rate and the overall network performance
Quality of Service (QoS) requirements	The requirements for reliability, delay, and throughput for the different types of data transmitted in the network
Simulation time	The duration of the simulation, which affects the accuracy and reliability of the simulation results

Table 2. Simulation Parameters for Analyzing the Simulation Result

Researchers can gain insights into the optimal design of protocols for energy-efficient data dissemination in VANETs by varying these parameters and analyzing their impact on the performance of the proposed cross-layer protocol. This allows the researchers to gain insights into the optimal design of protocols.

V. Conclusion

Within the scope of this work, we provided a cross-layer design method with the goal of enhancing the energy efficiency of data distribution within VANETs. The method of design makes use of several different energy-saving strategies, such as priority-based message scheduling, cooperative communication, power control, and sleep mode, amongst others. The findings of the simulation indicate that the approach to design that was recommended resulted in a significant reduction in energy consumption and an improvement in the sustainability of VANETs. The method of design that was suggested can be utilized in a variety of various VANET configurations to enhance the energy efficiency and sustainability of such systems. Investigating the effect that varied vehicle densities, mobility patterns, and alternative network topologies have on the performance of the suggested design method is one of the future directions of research that will be pursued. In addition, there is a need for practical tests to validate the success of the proposed design method in actual VANETs in the real world.

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