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DRIVE: Dynamic Routing in Vehicular Environments - An Ensemble Routing Algorithm (AERA)

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Abstract:

Vehicular Ad Hoc Networks (VANETs) enable efficient communication between vehicles and infrastructure, facilitating intelligent transportation systems. However, achieving reliable and efficient data routing in dynamic and unpredictable vehicular environments remains a significant challenge due to high mobility, frequent topology changes, and variable network density. This paper introduces A Dynamic Routing in Vehicular Environments (DRIVE) designed to optimize packet delivery performance in VANETs. The proposed algorithm incorporates real-time vehicular mobility patterns such as Commuter Traffic Patterns, Event-Based Patterns, and Temporal and Spatial Patterns, road topology awareness, and a hybrid approach combining Hybrid Wireless Mesh Protocol (HWMP) and Temporally Ordered Routing Algorithm (TORA). Simulation results demonstrate significant improvements in packet delivery ratio, reduced end-to-end latency, and enhanced scalability compared to existing protocols. The findings highlight the potential of the proposed algorithm to support robust and efficient communication in next-generation vehicular networks.

Keywords: Vehicular Ad Hoc Networks (VANETs), Dynamic Routing, DRIVE, Hybrid Wireless Mesh Protocol (HWMP), Temporally Ordered Routing Algorithm (TORA).

1. Introduction

Vehicles and roadside infrastructure can communicate with each other thanks to Vehicular Ad Hoc Networks (VANETs), a specific kind of Mobile Ad Hoc Networks (MANETs). By enabling communication between vehicles and infrastructure, VANETs are intended to support intelligent transportation systems (ITS). This dynamic network is essential for improving driving convenience, traffic efficiency, and road safety. The process of identifying and modifying the best routes for data packets in response to modifications in network topology is known as dynamic routing in VANETs. Unlike static routing, where routes are pre-established and rarely change, dynamic routing adapts to the highly mobile nature of VANETs, where vehicles constantly change their positions, speeds, and connectivity. Vehicles in VANETs move at varying speeds, causing frequent changes in network connections. Dynamic routing algorithms must adapt rapidly to these changes to ensure reliable communication. Many VANET applications, such as collision warnings and emergency notifications, require minimal delays. Routing protocols must prioritize low-latency communication. VANETs often consist of large numbers of nodes (vehicles), necessitating routing protocols that can scale effectively without compromising performance. Due to factors like vehicle density and environmental obstacles, connectivity in VANETs is often inconsistent. Routing protocols must account for these disruptions and find alternative paths when needed.

In the context of VANETs, a highly dynamic topology refers to the frequent and unpredictable changes in network structure caused by vehicle mobility. Unlike static networks, where node positions remain relatively constant, the high speeds and varying movement patterns of vehicles (e.g., on highways, in urban environments) result in continuous modifications to connectivity. These changes affect the availability, reliability, and efficiency of communication paths between nodes. Due to the rapid movement of vehicles, connections between nodes are often short-lived, requiring constant route adjustments. Traffic conditions (e.g., congestion in urban areas vs. sparse vehicles on highways) lead to fluctuating node densities, impacting connectivity and routing performance. Vehicle speeds and directions vary based on road conditions, driver behavior, and traffic regulations, making network topology highly unpredictable. In fast-moving scenarios, such as highway traffic, vehicles are within each other's communication range only briefly, limiting the time available for data exchange. In this paper, the proposed approach uses highly dynamic topology of VANETs enables innovative solutions for improving road safety, traffic efficiency, and passenger convenience. By leveraging real-time vehicle movement data, VANETs can support adaptive and context-aware applications, such as dynamic traffic management, emergency response coordination, and smart navigation.

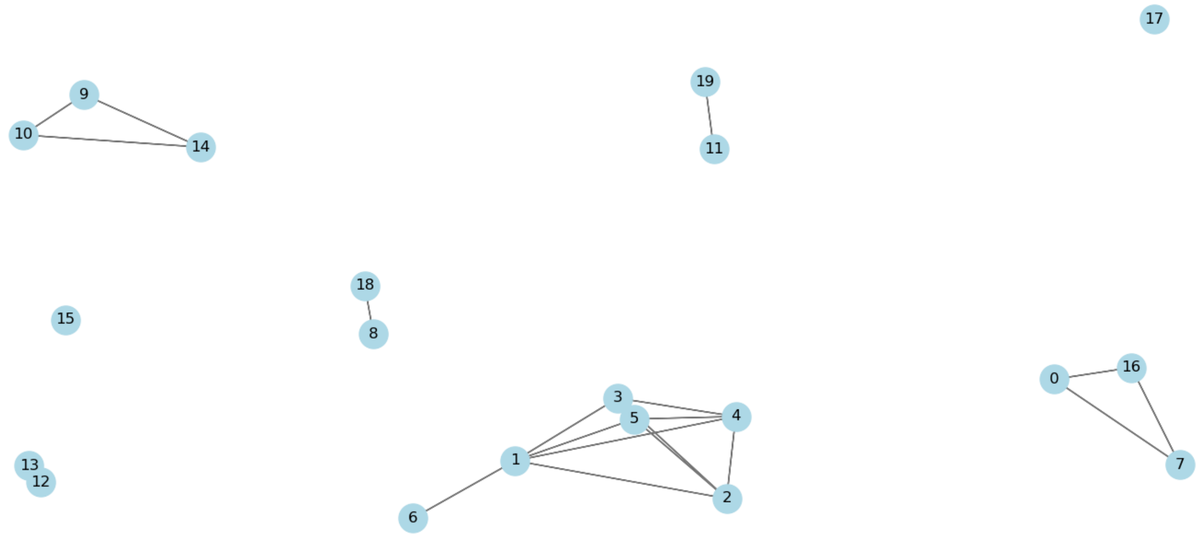

Figure 1: Sample Network in VANETS

2. Literature Survey

A unique trust cascading-based emergency message dissemination (TCEMD) model was suggested by Liu et al. [8] that effectively integrates entity-oriented trust values into data-oriented trust evaluation. According to the suggested model, emergency messages can be distributed among neighbouring vehicles in a trust cascading fashion when an emergency event (such as an obstruction in front of the road) occurs. The entity-oriented trust values, which are included in the messages and are assessed and updated by utilising the trust certificates, are adopted as significant weights. A number of simulations and studies are then carried out in a typical highway setting, and the findings show that the suggested model performs noticeably better than the current models in a number of instances. Ghazi et al. [9] offer a thorough analysis of current research on the distribution of emergency messages. Numerous authors have put up various plans that provide dependable and effective emergency message distribution. The ITS, IoT, clustering, priority messaging, SDN, fog computing, and 5G networks serve as the foundation for these investigations. Both the conventional city and the smart city perspectives were included in the investigation for a definitive study. Marques et al. [10] proposed techniques that make use of the position, direction, speed, number of nearby cars, and features of the city area to ensure that the message reaches every vehicle as quickly as possible with the least amount of network overhead. We set up an emulation platform with actual connectivity and mobility data to demonstrate the efficacy of our tactics. According to our findings, the delivery rate ranges from 92% to 100% for different vehicle speeds and densities, as well as for different communication technology range and zone sizes of relevance. An urban VANET emergency data routing protocol called Parking-Assisted Spider-Web Routing Protocol (PASRP) was proposed by Liu et al. [11]. In PASRP, a digital map and a geographic information system are used to create a spider-web gearbox model based on the parking area. The transmission path from the source vehicle to the destination vehicle is obtained by sending two control messages, request-spider and confirm-spider. The transmission path with the least latency is chosen. Lastly, the simulation results show that for emergency data protocols, the suggested PASRP works better than the current greedy perimeter stateless routing and transmission system. By enhancing location accuracy, Afrashteh et al. [12] propose a Route Segmented Broadcast Protocol based on Radio Frequency identification technology (RSBP-RF) to solve GPS-based issues and boost emergency message broadcasting efficiency. The path is segmented and a position-aware method is provided by integrated passive RFID tags in this protocol. Each vehicle in RSBP-RF sends a beacon to its neighbours instantly after crossing the tags to indicate its position. The success of the suggested protocol has been confirmed by the outcomes of the simulations carried out in the NS-3 tool in terms of dissemination performance, relay node selection accuracy, end-to-end delay, delivery ratio, one-hop delay, and collision ratio. The Adaptive Carrier Sense Multiple Access/Collision Avoidance (Ada-CSMA/CA) protocol was proposed by Alkhalifa et al. [13]. Segment-based forwarder selection (SFS), which uses the fuzzy-Vikor approach to choose the best forwarder, is used in safety message broadcasting. This minimises the broadcast storm by choosing the best forwarder to broadcast safety messages. We have performed simulations on the Veins framework, which is based on the Omnet++ and SUMO simulator, in order to validate the suggested NSSC. In terms of the subsequent metrics—reachability, average number of collisions, duplicate data packets, latency, packet delivery ratio, and throughput—the obtained findings are favourable. A dynamic clustering (DC) model for VANET in an urban setting is proposed by Cheng et al. [14] and is based on connectivity prediction. Initially, we present a connection prediction method

(CP) based on a vehicle node's attributes and the relative features of other vehicle nodes. After that, we develop a DC model based on vehicle node density and connectivity. Lastly, we introduce a routing technique based on the DC model to achieve reliable communications between vehicle nodes. The experimental findings demonstrate that the suggested CP can outperform the geographic routing based on multilayer perceptrons and predictive locations in terms of mistake rate. For the Reduced Broadcast Overhead Scheme for Emergency Message Dissemination (RBO-EM), Ullah et al. [15] suggest a clustering technique. In a high mobility scenario, RBO-EM relies on mobility measurements to preserve message dependability, prevent communication overhead, and reinforce cluster formation. In addition, we limit the amount of retransmissions by introducing relay nodes based on predicted connection stability. Different traffic densities and speeds are used to compare RBO-EM to other top schemes. According to simulation studies, RBO-EM allows for a respectable performance improvement in terms of message reliability, coverage, and end-to-end latency. For VANETs, Karabulut et al. [16] suggested a novel OFDMA-based efficient cooperative MAC protocol (OEC-MAC). Mechanisms for assigning subcarrier channels and gaining access are offered. This mechanism is described for both picking the best relay and the suitable transmission mode. To encourage cooperative communication, new control messages have been defined. The OEC-MAC protocol guarantees a notable boost in throughput and also meets the stringent delay requirement of 100 ms on VANETs for safety messages (sm), according to numerical findings that are presented. To create and manipulate mental representations of specified information, Yamini et al. [18] suggested an effective trust establishment-based routing evidence strategy (ETERE). I-Trust, a probabilistic node misbehavior detection system, is proposed here for safe MANET routing in the direction of the ETERE scheme. The core idea behind I-Trust is to provide a trusted authority that is regularly available to make decisions about a node's behavior based on the routing information that has been obtained and with self- and coordinated monitoring. According to the simulation results, the suggested ETERE scheme outperforms current approaches, increasing the network's PDR and throughput by up to 28% and 34%, respectively.

Hybrid Wireless Mesh Protocol (HWMP)

In VANETs, routing protocols play a crucial role in ensuring reliable and efficient communication. The Hybrid Wireless Mesh Protocol (HWMP), part of the IEEE 802.11s standard, is a robust routing protocol designed for wireless mesh networks, which can be adapted effectively for VANETs due to its hybrid nature and flexibility. HWMP is a hybrid routing protocol that combines proactive and reactive routing strategies [19]. This dual approach allows it to optimize for different network conditions, making it suitable for VANETs, which experience frequent topology changes and varying traffic densities. HWMP operates in two primary modes:

Proactive Mode:

- Based on the tree-based routing mechanism.
- Utilizes a root node (e.g., a fixed roadside unit or base station) to periodically broadcast routing information.
- Best suited for scenarios with stable or semi-stable infrastructure, such as V2I communication.

Reactive Mode:

- Uses on-demand route discovery to establish paths between nodes when no existing route is available.
- Ideal for highly dynamic V2V communication, where establishing routes proactively may be inefficient.

VANETs are characterized by rapidly changing network topologies due to high-speed vehicle movement. HWMP's hybrid design allows it to adapt to these changes by switching between proactive and reactive modes as needed. The protocol efficiently handles varying network sizes, from small clusters of vehicles to large-scale urban networks, by dynamically managing routing overhead. HWMP supports Quality of Service (QoS) by selecting routes based on metrics like link quality and airtime cost, ensuring reliable and timely data delivery.

Temporally Ordered Routing Algorithm (TORA)

The Temporally Ordered Routing Algorithm (TORA) is a highly adaptive, distributed, and scalable routing protocol designed for dynamic networks like VANETs. TORA operates on the principle of link reversal, providing a flexible mechanism to establish, maintain, and repair routes in a decentralized manner. It focuses on reducing routing overhead while adapting quickly to network topology changes. Unlike traditional routing protocols, TORA maintains a directed acyclic graph (DAG) rooted at the destination, ensuring loop-free routing paths. TORA is well-suited for VANETs where network topology changes rapidly due to vehicle mobility [20]. It updates routes only in the vicinity of topology changes, minimizing network-wide disruptions. It supports multiple routing paths to a destination, enhancing fault tolerance and reliability in VANETs. Routes are established and maintained only when required, conserving bandwidth and resources. Routing decisions and updates are localized, reducing the need for global knowledge of the network.

Step 1: Route Creation:

- TORA establishes a DAG from the source to the destination using a height metric for nodes.
- Each node in the DAG has a height that determines its direction of data flow.

Step 2: Route Maintenance:

- When a link failure occurs, TORA employs link reversal and propagates updates only locally, avoiding the need to rebuild the entire route.

Step 3: Route Erasure:

- If a destination becomes unreachable, TORA initiates a route erasure process to remove invalid routes.

Simulation Results

In NS3 (Network Simulator 3), simulating a network with 50 or 100 nodes involves setting up various configurations, including the type of network (e.g., ad hoc, wireless, or wired), protocols (like TCP, UDP, or custom protocols), and performance metrics to analyze (such as throughput, delay, or packet loss).

$$\text{Throughput (T)} = \frac{\text{Number of Packets Received}}{\text{Total Time}}$$

Delay (D) = Transmission Delay + Propagation Delay + Queuing Delay + Processing Delay

$$\text{Packet Loss (PL)} = 1 - \frac{\text{No fo Packets Received}}{\text{Total Number of Packets Sent}}$$

Table 1: Simulation Setup

Network Simulators	NS3
Mobility Simulators	VanetMobiSim
Vehicular Mobility Model	car-following
Communication Model	IEEE 802.11p (DSRC)
Nodes	50,100, 200

3. Results and Discussions

With 50 nodes, the network may still function efficiently, but congestion could begin to appear as more nodes are added. If there's too much traffic or inefficient routing, throughput might decrease due to packet collisions or delays in routing. The delay might be relatively low at this scale, but as nodes are more distributed, especially in mobile or wireless networks, delays can increase due to routing overhead or signal degradation. Likely to be low at this scale, as there are fewer nodes competing for bandwidth and resources. However, in highly congested areas or with high traffic, packet loss might increase.

At 100 nodes, the throughput might decrease due to congestion, network collisions, or interference between nodes. More nodes generally mean more routing and coordination, which can introduce overhead. Delay increases as the number of nodes grows, particularly if the routing protocols aren't optimized. A larger number of nodes require more time to route packets, and in mobile scenarios, frequent changes in network topology can increase delays. The packet loss rate typically increases with more nodes, especially if the network becomes congested, and there is not enough bandwidth to handle the data load efficiently.

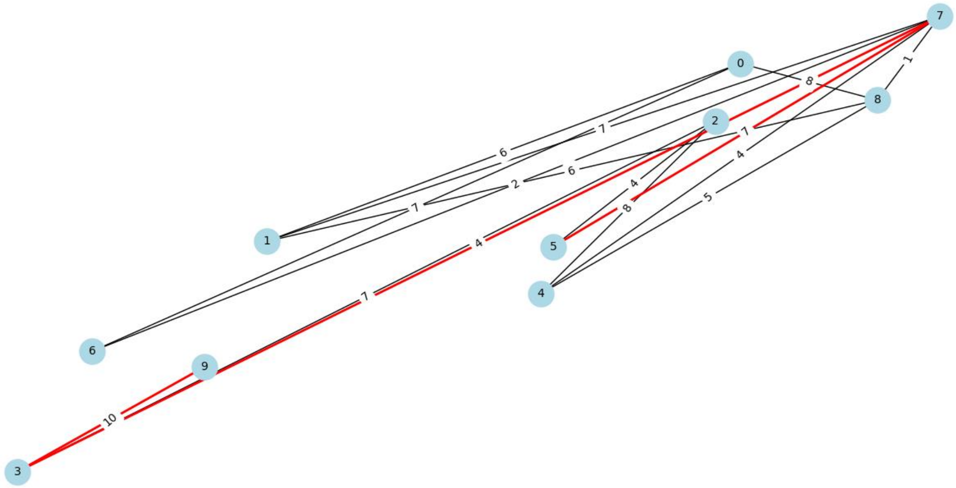

Figure 2: Simulation results of HWMP

Starting route discovery...
Node 1: Broadcasting RREQ for 4
Node 2: Received RREQ for 4 from Node 1
Node 2: Broadcasting RREQ for 4
Node 4: Received RREQ for 4 from Node 2
Node 4: Destination reached. Sending RREP back.
Node 2: Updated routing table: {4: 1}
Node 3: Received RREQ for 4 from Node 1
Node 3: Broadcasting RREQ for 4
Node 4: Received RREQ for 4 from Node 3
Node 4: Destination reached. Sending RREP back.
Node 3: Updated routing table: {4: 1}

Graph Representation: Each node represents a vehicle; edges represent connections with weights indicating distance.

Dynamic Routing: The shortest path is calculated dynamically using Dijkstra's algorithm (a core principle in HWMP).

Simulation Graph: The graph shows nodes, edges, and the computed route in red.

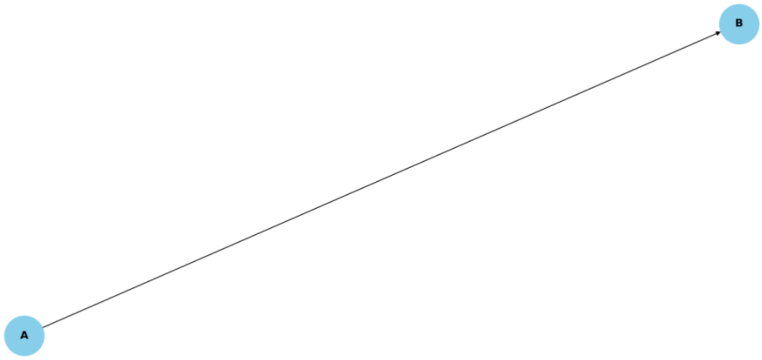

Figure 3: Simulation of TORA (Edge added: A -> B)

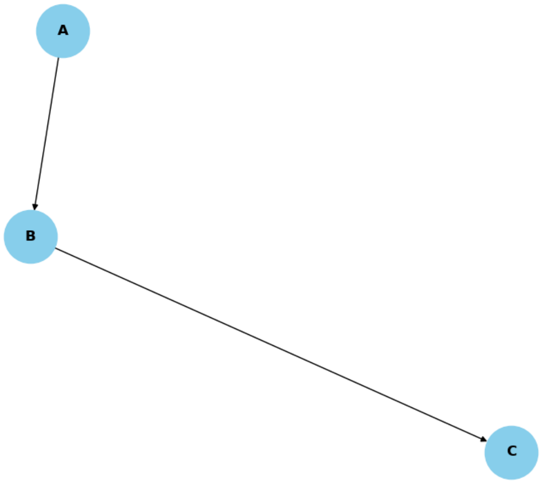

Figure 4: Simulation of TORA (Edge added: B -> C)

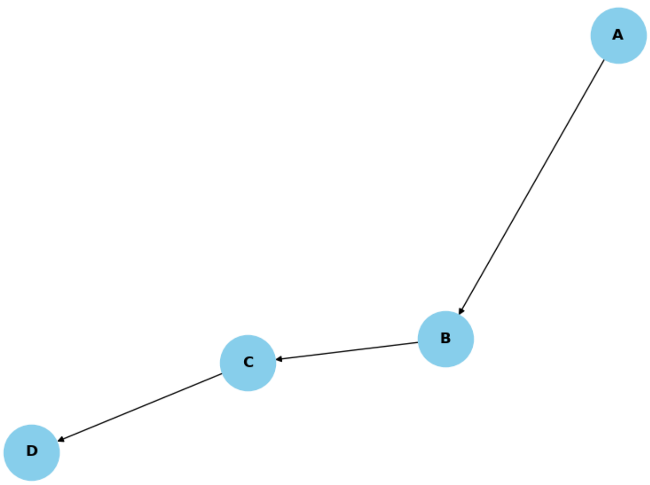

Figure 5: Simulation of TORA (Edge added: C -> D)

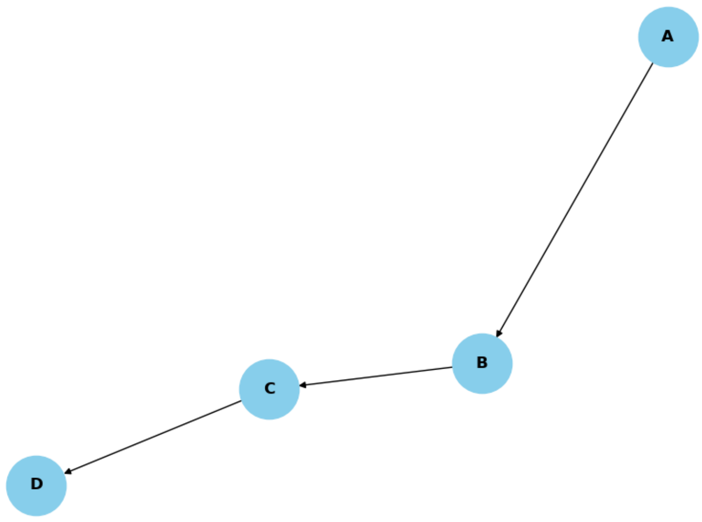

Figure 6: Simulation of TORA (Edge added: D -> E)

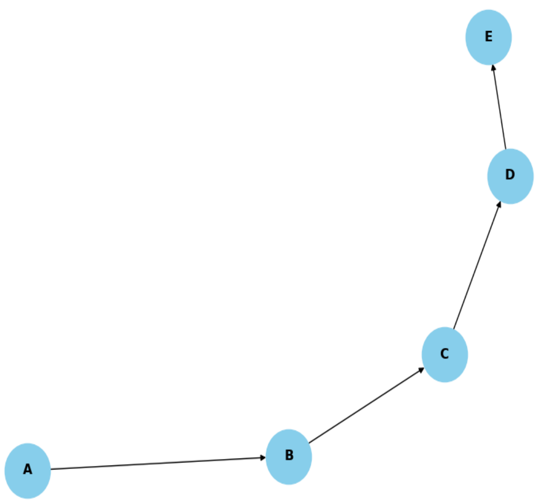

Figure 7: Heights updated: {'A': 8, 'B': 9, 'C': 1, 'D': 5, 'E': 10}

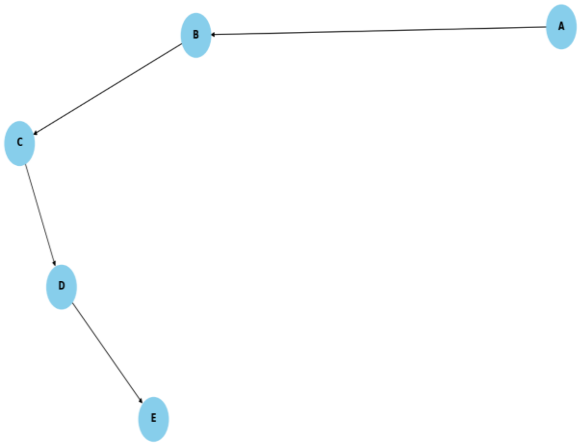

Figure 8: Route created: A -> B -> C -> D -> E

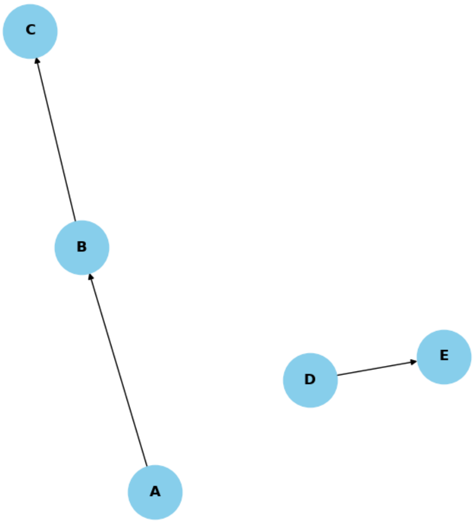

Figure 9: Maintaining route: A -> B -> C -> D -> E

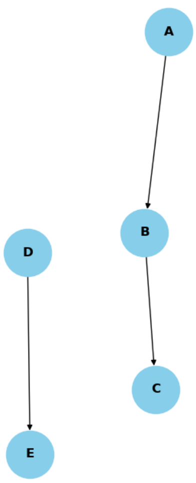

Figure 10: Edge removed: C -> D

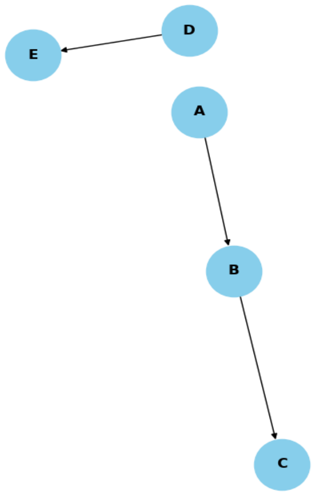

Figure 11: Heights updated: {'A': 8, 'B': 4, 'C': 4, 'D': 10, 'E': 9}. No route found from A to E. Route deleted: A -> E

Table 1: Overall performances of various routing algorithms in VANET's for 50 Nodes

Algorithms	Throughput	Delay (ms)	Packet Loss
Hybrid Wireless Mesh Protocol (HWMP)	76%	141	13%
ETERE [18]	85%	120	8%
TORA [20]	78%	110	5%
Proposed	92%	88	3%

Table 2: Overall performances of various routing algorithms in VANET's for 100 Nodes

Algorithms	Throughput	Delay (ms)	Packet Loss
Hybrid Wireless Mesh Protocol (HWMP)	89%	151	23%
ETERE [18]	112%	135	21%
TORA [20]	121%	109	14%
Proposed	141%	95	9%

Table 3: Overall performances of various routing algorithms in VANET's for 200 Nodes

Algorithms	Throughput	Delay (ms)	Packet Loss
Hybrid Wireless Mesh Protocol (HWMP)	121%	211	33%
ETERE [18]	112%	171	28%
TORA [20]	101%	145	21%
Proposed	97%	123	17%

4. Conclusion

In the context of vehicular environments, dynamic routing presents a complex challenge due to the high mobility of vehicles and rapidly changing network topologies. The Ensemble Routing Algorithm (AERA), combining elements of the Hybrid Wireless Mesh Protocol (HWMP) and the Temporally Ordered Routing Algorithm (TORA), addresses these challenges by leveraging the strengths of both protocols. AERA demonstrates enhanced scalability and efficiency by dynamically switching between HWMP and TORA based on real-time network conditions. The proactive-reactive hybrid approach ensures optimal resource usage, reducing overhead and improving packet delivery rates in various vehicular environments. Finally, the proposed approach has a throughput of 92%, delay (ms) of 88, and Packet Loss of 3% for 50 Nodes. For 100 nodes, throughput is 141%, delay (ms) is 95, and packet loss is 9%, and for 200 nodes, throughput is 97%, delay (ms) is 123, and packet loss is 17%. The comparison between the existing algorithms and the proposed algorithms shows better performance in small and large networks. AERA successfully caters to the diverse Quality of Service (QoS) demands in vehicular environments, such as low-latency communication for safety-critical applications and high-throughput for infotainment services. The combination ensures adaptability to varying vehicular densities, speeds, and communication requirements. AERA effectively combines HWMP's proactive efficiency and TORA's reactive adaptability, providing a robust solution for dynamic vehicular routing. This ensemble algorithm enhances the reliability, scalability, and performance of vehicular networks, making it suitable for real-world deployment in intelligent transportation systems. Future research could explore integrating AERA with emerging technologies like 5G, edge computing, and machine learning for further optimization and real-time decision-making.

References

1. A. Abuashour and M. Kadoch, "An Intersection Dynamic VANET Routing Protocol for a Grid Scenario," 2017 IEEE 5th International Conference on Future Internet of Things and Cloud (FiCloud), Prague, Czech Republic, 2017, pp. 25-31, doi: 10.1109/FiCloud.2017.19.
2. M. Abdollahi et al., "Dynamic Routing Protocol Selection in Multi-Hop Device-to-Device Wireless Networks," in IEEE Transactions on Vehicular Technology, vol. 71, no. 8, pp. 8796-8809, Aug. 2022, doi: 10.1109/TVT.2022.3172923.
3. R. Han, J. Shi, Q. Guan, F. Banoori and W. Shen, "Speed and Position Aware Dynamic Routing for Emergency Message Dissemination in VANETs," in IEEE Access, vol. 10, pp. 1376-1385, 2022, doi: 10.1109/ACCESS.2021.3138960.
4. T. Zhang, C. Xu, B. Zhang, J. Shen, X. Kuang and L. A. Grieco, "Toward Attack-Resistant Route Mutation for VANETs: An Online and Adaptive Multiagent Reinforcement Learning Approach," in IEEE Transactions on Intelligent Transportation Systems, vol. 23, no. 12, pp. 23254-23267, Dec. 2022, doi: 10.1109/TITS.2022.3198507.
5. A. R. Deshmukh, P. Nirmal and S. S. Dorle, "A New Approach for Position Based Routing Protocols Based on Ant Colony Optimization (ACO) Technique in Vehicular Ad Hoc Network (VANET)," 2021 International Conference on Intelligent Technologies (CONIT), Hubli, India, 2021, pp. 1-5, doi: 10.1109/CONIT51480.2021.9498332.
6. A. Ullah, X. Yao, S. Shaheen, and H. Ning, "Advances in position based routing towards ITS enabled FoG-oriented VANET—A survey," IEEE Trans. Intell. Transp. Syst., vol. 21, no. 2, pp. 828–840, Feb. 2020.

7. H. Khelifi, S. Luo, B. Nour, H. Moungla, Y. Faheem, R. Hussain, and A. Ksentini, "Named data networking in vehicular ad hoc networks: Stateof-the-art and challenges," IEEE Commun. Surveys Tuts., vol. 22, no. 1, pp. 320–351, 1st Quart., 2020.
8. Z. Liu, J. Weng, J. Ma, J. Guo, B. Feng, Z. Jiang, and K. Wei, "TCEMD: A trust cascading-based emergency message dissemination model in VANETs," IEEE Internet Things J., vol. 7, no. 5, pp. 4028–4048, May 2020.
9. M. U. Ghazi, M. A. K. Khattak, B. Shabir, A. W. Malik, and M. S. Ramzan, "Emergency message dissemination in vehicular networks: A review," IEEE Access, vol. 8, pp. 38606–38621, 2020.
10. M. Marques, C. Senna, and S. Sargento, "Evaluation of strategies for emergency message dissemination in VANETs," in Proc. IEEE Symp. Comput. Commun. (ISCC), Rennes, France, Jul. 2020, pp. 1–6.
11. H. Liu, T. Qiu, X. Zhou, C. Chen, and N. Chen, "Parking-area-assisted spider-web routing protocol for emergency data in urban VANET," IEEE Trans. Veh. Technol., vol. 69, no. 1, pp. 971–982, Jan. 2020.
12. M. Afrashteh and S. Babaie, "A route segmented broadcast protocol based on RFID for emergency message dissemination in vehicular ad-hoc networks," IEEE Trans. Veh. Technol., vol. 69, no. 12, pp. 16017–16026, Dec. 2020.
13. I. S. Alkhalifa and A. S. Almogren, "NSSC: Novel segment based safety message broadcasting in cluster-based vehicular sensor network," IEEE Access, vol. 8, pp. 34299–34312, 2020.
14. J. Cheng, G. Yuan, M. Zhou, S. Gao, Z. Huang, and C. Liu, "A connectivity-prediction-based dynamic clustering model for VANET in an urban scene," IEEE Internet Things J., vol. 7, no. 9, pp. 8410–8418, Sep. 2020.
15. S. Ullah, G. Abbas, Z. H. Abbas, M. Waqas, and M. Ahmed, "Rbo-em: Reduced broadcast overhead scheme for emergency message dissemination in vanets,'' IEEE Access, vol. 8, pp. 175205–175219, 2020.
16. M. A. Karabulut, A. F. M. S. Shah, and H. Ilhan, "OEC-MAC: A novel OFDMA based efficient cooperative MAC protocol for VANETS," IEEE Access, vol. 8, pp. 94665–94677, 2020.
17. F. Chbib, L. Khoukhi, W. Fahs, J. Haydar and R. Khatoun, "A cross-layered scheme for multichannel and reactive routing in vehicular ad hoc networks", Trans. Emerg. Telecommun. Technol., vol. 33, no. 7, Jul. 2022.
18. K. A. P. Yamini, J. Stephy, K. Suthendran and V. Ravi, "Improving routing disruption attack detection in MANETs using efficient trust establishment", Trans. Emerg. Telecommun. Technol., vol. 33, no. 5, May 2022.
19. T. Poongodi, M. S. Khan, R. Patan, A. H. Gandomi and B. Balusamy, "Robust defense scheme against selective drop attack in wireless ad hoc networks", IEEE Access, vol. 7, pp. 18409-18419, 2019.
20. K. Sakai, M.-T. Sun, W.-S. Ku, J. Wu and T. H. Lai, "Secure data communications in wireless networks using multi-path avoidance routing", IEEE Trans. Wireless Commun., vol. 18, no. 10, pp. 4753-4767, Oct. 2019.