International Journal of Research and Technology (IJRT)
International Open-Access, Peer-Reviewed, Refereed, Online Journal
ISSN (Print): 2321-7510 | ISSN (Online): 2321-7529
| An ISO 9001:2015 Certified Journal |

# Multi-Agent AI Systems for Cooperative Communication in Hybrid MANET-VANET Architectures

**[1]Divyansh Singh Narvariya, [2]Prof. Kanchan Thool**
[1]Research Scholar, School of Engineering & Technology, Samrat Vikramaditya Vishwavidyalaya, Ujjain, Madhya Pradesh
[2]School of Engineering & Technology, Samrat Vikramaditya Vishwavidyalaya, Ujjain, Madhya Pradesh

**ABSTRACT**
The rapid growth of intelligent transportation systems, mobile wireless communication, Internet of Things (IoT), autonomous vehicles, and smart city infrastructures has significantly increased the demand for intelligent, adaptive, and reliable communication frameworks. Traditional Mobile Ad Hoc Networks (MANETs) and Vehicular Ad Hoc Networks (VANETs) face several challenges such as dynamic topology changes, high node mobility, routing instability, communication delay, packet loss, network congestion, scalability limitations, and security vulnerabilities. Conventional routing protocols are often unable to provide efficient communication performance in highly dynamic wireless environments due to their static and non-adaptive routing mechanisms. Therefore, the development of intelligent cooperative communication systems has become essential for supporting next-generation wireless communication networks. This research proposes a Multi-Agent Artificial Intelligence (AI)-based cooperative communication framework for Hybrid MANET-VANET architectures. The proposed framework integrates the flexibility of MANETs with the vehicular communication capabilities of VANETs to create a decentralized, adaptive, and intelligent communication environment.

**Keywords:** Agentic AI, MANET, Quality of Service (QoS), Autonomous Agents, Reinforcement Learning, Network Optimisation, Multi-Agent System

## 1. INTRODUCTION TO WIRELESS AD HOC NETWORKS

Wireless Ad Hoc Networks represent one of the most significant advancements in modern communication technology, enabling communication among mobile devices without relying on fixed infrastructure or centralized administration. Unlike conventional wireless networks that depend on access points, base stations, or routers for communication management, ad hoc networks operate in a decentralized manner where each node participates actively in data transmission and routing. These networks are highly dynamic, self-configuring, and adaptable, making them suitable for environments where fixed communication infrastructure is unavailable, damaged, or impractical to deploy [1].

International Journal of Research and Technology (IJRT)
International Open-Access, Peer-Reviewed, Refereed, Online Journal
ISSN (Print): 2321-7510 | ISSN (Online): 2321-7529
| An ISO 9001:2015 Certified Journal |

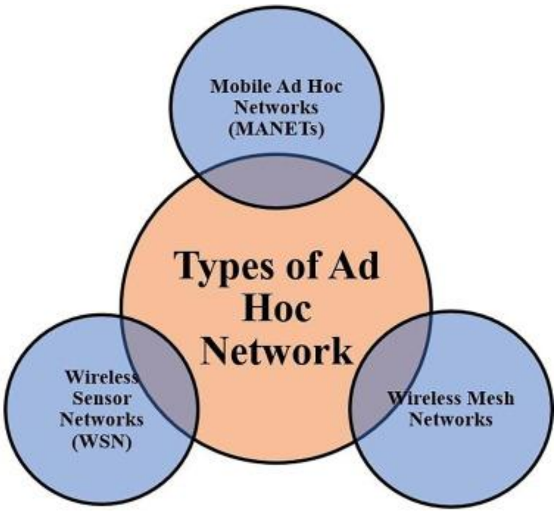


**Fig.1.1 ADHOC and WSN.**

## 2. DEFINITION OF WIRELESS COMMUNICATION

Wireless communication refers to the transmission of information, signals, data, voice, video, or multimedia between two or more devices without the use of physical wired connections such as cables or optical fibers. Instead of relying on guided media, wireless communication utilizes electromagnetic waves to transfer information through free space. These electromagnetic waves may include radio waves, microwaves, infrared waves, or satellite signals depending on the communication technology and application requirements [2].

Wireless communication has become one of the fundamental technologies of the modern digital era due to its flexibility, mobility, scalability, and ease of deployment. It enables users and devices to communicate anytime and anywhere without being physically connected to a network infrastructure. The development of wireless communication technologies has revolutionized various sectors including telecommunications, transportation, healthcare, defense, industrial automation, smart cities, and Internet of Things (IoT) systems [3].

## 3. OVERVIEW OF AD HOC NETWORKS

Ad Hoc Networks are decentralized wireless communication networks that operate without relying on any fixed infrastructure, centralized administration, or predefined network architecture. In these networks, multiple wireless devices or nodes communicate directly with one another using radio signals and collaboratively maintain network connectivity through self-organizing mechanisms. The term “ad hoc” refers to a temporary or spontaneously formed arrangement designed for a specific purpose. Similarly, Ad Hoc Networks are dynamically created whenever a group of wireless nodes comes within communication range and establishes communication links automatically without requiring routers, access points, or base stations [4].

In an Ad Hoc Network, every node functions both as a communication host and as a router. As a host, a node generates and receives data, while as a router, it forwards packets to neighboring nodes to enable communication between distant devices through multi-hop transmission. Multi-hop communication is one of the most important characteristics of ad hoc networks because nodes that are outside the direct transmission range can still communicate through intermediate nodes. This collaborative communication mechanism increases network coverage and enables efficient data transmission in dynamic and infrastructure-less environments [5].

## 4. PROBLEMS IN CONVENTIONAL MANET ROUTING

Mobile Ad Hoc Networks (MANETs) are decentralized wireless communication networks composed of mobile nodes that communicate without relying on fixed infrastructure or centralized administration. Each node in a MANET functions both as a communication device and as a router responsible for forwarding packets to other nodes. MANETs are widely used in military communication, disaster management, emergency response systems, intelligent transportation, wireless sensor applications, and mobile computing environments due to their flexibility, rapid deployment capability, and infrastructure-less operation. However, despite these advantages, conventional MANET routing protocols face numerous challenges and limitations that significantly affect communication reliability, network efficiency, scalability, and Quality of Service (QoS) [6].

## 5. CHALLENGES IN VANET COMMUNICATION

Vehicular Ad Hoc Networks (VANETs) are specialized forms of Mobile Ad Hoc Networks (MANETs) designed to support intelligent communication among vehicles, roadside infrastructure, traffic management systems, and other transportation entities. VANETs enable Vehicle-to-Vehicle (V2V), Vehicle-to-Infrastructure (V2I), and Vehicle-to-Everything (V2X) communication for applications such as traffic management, road safety, autonomous driving, emergency communication, infotainment services, and smart transportation systems. VANET technology plays a significant role in the development of Intelligent Transportation Systems (ITS), smart cities, and autonomous vehicular networks [7].

Despite their potential benefits, VANET communication systems face numerous technical and operational challenges due to high vehicle mobility, rapidly changing network topology, heterogeneous communication environments, strict Quality of Service requirements, and real-time communication demands. Conventional communication protocols and routing mechanisms are often unable to provide reliable and adaptive communication under highly dynamic vehicular conditions. The major challenges associated with VANET communication are discussed below [8].

High Mobility of Vehicles

One of the most significant challenges in VANET communication is the extremely high mobility of vehicles. Vehicles move at varying speeds and directions depending on road conditions, traffic density, and driving behavior. In highways and urban transportation environments, vehicles may rapidly enter or leave communication ranges, causing frequent changes in network topology.

## 6. PROPOSED METHODOLOGY-HYBRID ARCHITECTURE

Hybrid communication architecture represents an advanced networking framework that combines multiple wireless communication technologies, networking paradigms, and intelligent communication systems into a unified and cooperative communication environment. In the context of modern wireless communication research, Hybrid MANET-VANET architecture refers to the integration of Mobile Ad Hoc Networks (MANETs) and Vehicular Ad Hoc Networks (VANETs) to support efficient, adaptive, decentralized, and intelligent communication among mobile devices, vehicles, roadside infrastructure, Internet of Things (IoT) devices, drones, and edge-cloud systems. The hybrid architecture is designed to overcome the limitations of standalone MANET and VANET systems by enabling seamless communication interoperability, cooperative networking, and distributed intelligence across heterogeneous communication environments [9].

The rapid growth of intelligent transportation systems, autonomous vehicles, smart cities, IoT ecosystems, and next-generation wireless communication technologies has significantly increased the need for integrated communication frameworks capable of supporting real-time communication, dynamic mobility management, adaptive routing, and large-scale connectivity. Traditional communication systems generally operate independently and lack efficient coordination mechanisms for handling complex communication requirements in highly dynamic environments. Hybrid MANET-VANET architecture addresses these challenges by combining the strengths of MANETs and VANETs into a single cooperative communication framework.

In a Hybrid MANET-VANET architecture, communication occurs among various types of mobile and stationary nodes including vehicles, smartphones, wireless sensors, drones, roadside units (RSUs), IoT devices, emergency response systems, and communication infrastructure components. Each node participates actively in communication and may function as both a data transmitter and a router responsible for forwarding communication packets to neighboring nodes. Since the architecture is decentralized and infrastructure-less in many communication scenarios, nodes collaborate cooperatively to establish and maintain communication paths dynamically [10].

The MANET component of the hybrid architecture primarily supports communication among mobile wireless devices such as smartphones, laptops, sensors, tablets, wearable devices, drones, and portable communication systems. MANET communication is highly flexible and suitable for infrastructure-less environments where centralized communication infrastructure is unavailable or impractical. MANETs are widely used in military communication, disaster management, emergency rescue operations, remote area communication, and mobile collaborative systems. However, MANETs face challenges related to routing instability, limited scalability, communication delay, and dynamic topology changes [11-13].

## 7. COMMUNICATION LAYERS

Communication layers in Hybrid MANET-VANET architectures represent the structured framework used to manage data transmission, routing, communication control, and application services within wireless communication networks. These layers divide the communication process into different functional levels, where each layer performs specific tasks and interacts with adjacent layers to ensure efficient and reliable communication. The physical layer handles wireless signal transmission, modulation, frequency allocation, and communication hardware operations. The data link layer manages medium access control, error detection, channel access, and reliable frame transmission between neighboring nodes. The network layer is responsible for routing, packet forwarding, topology management, and path selection in dynamic communication environments. The transport layer ensures end-to-end communication reliability, flow control, congestion management, and data delivery optimization. The application layer supports intelligent transportation services, IoT applications, multimedia communication, traffic management, emergency systems, and autonomous vehicle operations. In Hybrid MANET-VANET systems, these communication layers work cooperatively with intelligent agents, vehicle nodes, mobile nodes, and roadside units to provide adaptive routing, secure communication, Quality of Service, and efficient real-time data exchange in highly dynamic wireless communication environments.

Infrastructure-less communication model

The infrastructure-less communication model is a decentralized wireless communication approach in which network nodes communicate directly with each other without relying on fixed infrastructure such as base stations, access points, or centralized servers. In Mobile Ad Hoc Networks (MANETs) and Hybrid MANET-VANET architectures, each node functions both as a communication device and as a router responsible for forwarding data packets to neighboring nodes through multi-hop communication. This model enables flexible and rapid network deployment in environments where communication infrastructure is unavailable, damaged, or impractical, such as disaster recovery, military operations, emergency response systems, intelligent transportation, and remote area communication.

## 8. COOPERATIVE NETWORKING FRAMEWORK

The cooperative networking framework is an intelligent communication model in which multiple network nodes collaborate and share resources to improve communication reliability, routing efficiency, data transmission, and overall network performance in wireless communication systems. In Hybrid MANET-VANET architectures, cooperative networking enables vehicle nodes, mobile nodes, roadside units, IoT devices, drones, and intelligent agents to work together for efficient information exchange and adaptive communication management. Instead of operating independently, nodes cooperate by forwarding packets, sharing network information, monitoring communication conditions, and assisting in routing decisions to maintain stable connectivity in highly dynamic environments.

## 9. MULTI-AGENT SYSTEM DESIGN

Multi-Agent System (MAS) design is a fundamental component in modern intelligent communication networks, particularly in Hybrid MANET-VANET architectures where decentralized communication, adaptive routing, and autonomous decision-making are essential. A Multi-Agent System consists of multiple intelligent software agents that interact, cooperate, and coordinate with one another to achieve common communication and networking objectives. These agents operate autonomously within the network and are capable of perceiving environmental conditions, processing communication data, making intelligent decisions, and performing specific networking tasks without centralized control. In highly dynamic wireless communication environments such as Mobile Ad Hoc Networks (MANETs) and Vehicular Ad Hoc Networks (VANETs), Multi-Agent Systems provide efficient solutions

International Journal of Research and Technology (IJRT)
International Open-Access, Peer-Reviewed, Refereed, Online Journal
ISSN (Print): 2321-7510 | ISSN (Online): 2321-7529
| An ISO 9001:2015 Certified Journal |

for handling routing instability, topology changes, congestion, communication delay, security threats, and resource management challenges.

## 10. RESULT AND SIMULATION

The figure shows the graphical user interface (GUI) of the Hybrid MANET–VANET AI System developed in MATLAB for evaluating the performance of the proposed intelligent routing framework. The GUI accepts network parameters such as Vehicle Speed, Packet Size, Simulation Time, and Transmission Range as inputs. After clicking the "Run Proposed Method" button, the system computes key performance metrics including Packet Delivery Ratio (PDR), Delay, Overhead, Energy Consumption, Packet Loss, Network Lifetime, Congestion Level, Quality of Service (QoS), and Security**.** This user-friendly interface enables quick analysis of network behavior and helps assess the effectiveness of the proposed AI-based MANET-VANET communication model under different simulation scenarios.

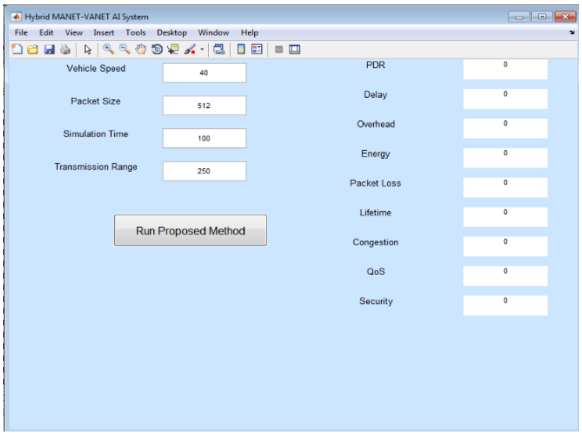


Fig.6.1 MATLAB Simulation .

Case-1 Variation of Communicaton input node

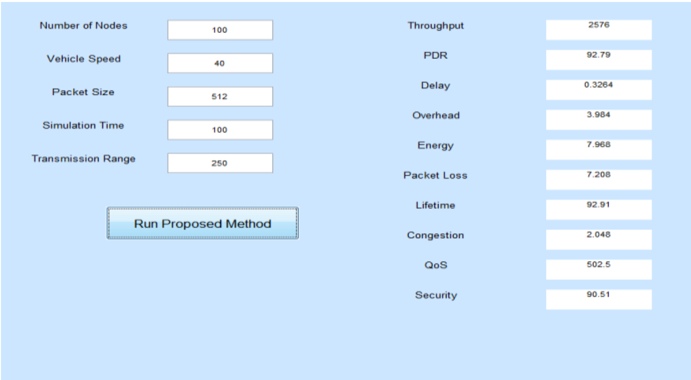


Fig.6.2 Obtained outputs.

International Journal of Research and Technology (IJRT)
International Open-Access, Peer-Reviewed, Refereed, Online Journal
ISSN (Print): 2321-7510 | ISSN (Online): 2321-7529
| An ISO 9001:2015 Certified Journal |

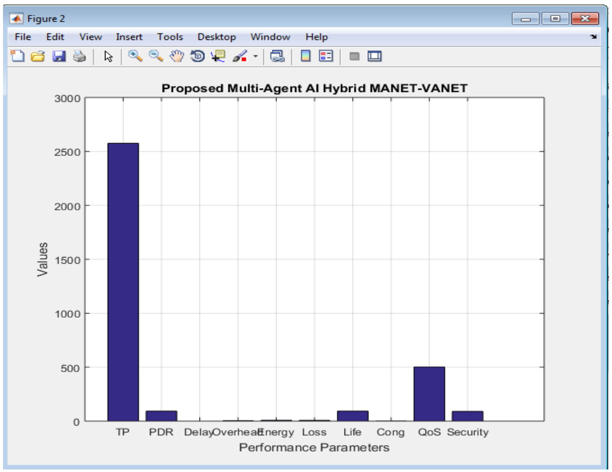


Fig.6.3 Ouput parameters

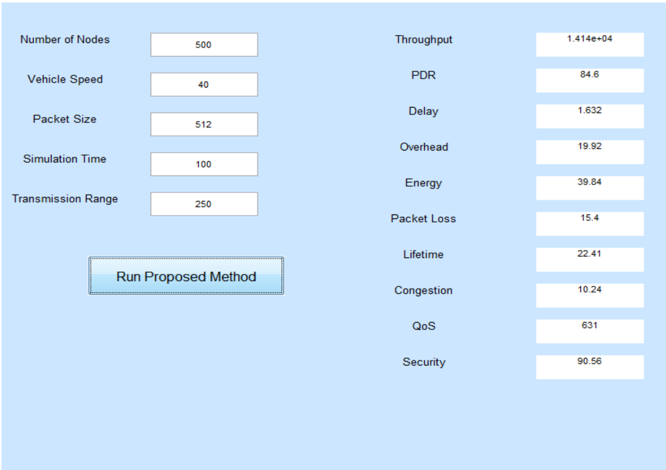


Fig.6.4 input and Output variation.

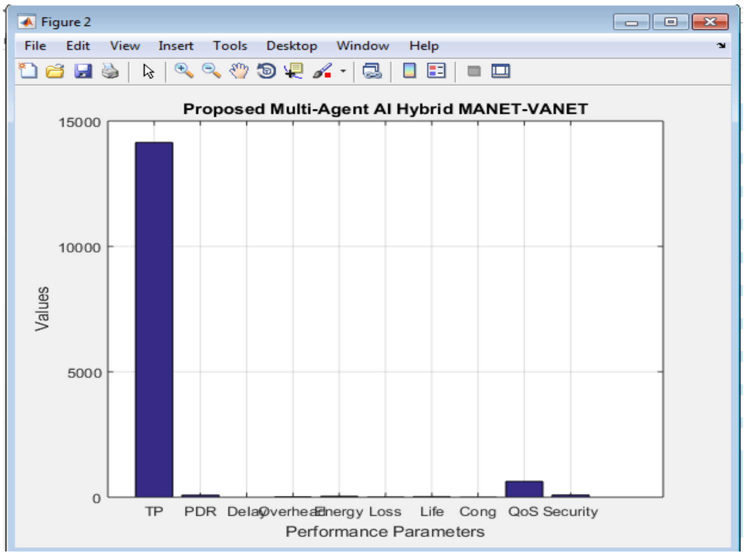


Fig.6.5 Output curve.

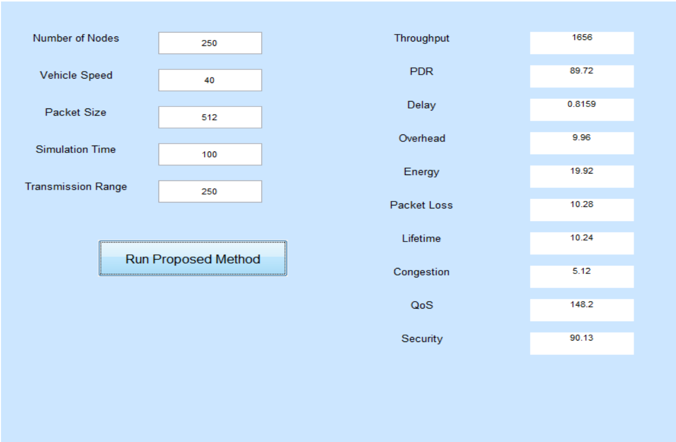


Fig.6.6 Outputs.

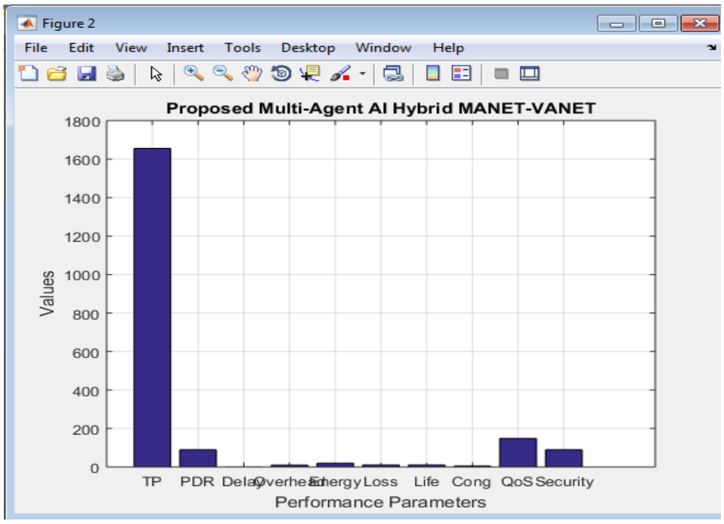


Fig.6.7 Case 1 Comparison.

The GUI shown in the figure represents a simulation-based performance evaluation system for a proposed vehicular/ad hoc network routing method. The user provides input parameters such as Number of Nodes (250), Vehicle Speed (40 m/s), Packet Size (512 bytes), Simulation Time (100 s), and Transmission Range (250 m). After clicking "Run Proposed Method", the system calculates important network performance metrics including Throughput (1656 kbps), Packet Delivery Ratio (89.72%), Delay (0.8159 s), Overhead (9.96%), Energy Consumption (19.92 J), Packet Loss (10.28%), Network Lifetime (10.24), Congestion (5.12%), QoS (148.2), and Security Level (90.13%). These results indicate that the proposed method achieves efficient data transmission, high packet delivery, low delay, improved quality of service, and enhanced network security under the given simulation conditions.

## 11. CONCLUSION

The rapid advancement of wireless communication technologies, intelligent transportation systems, Internet of Things (IoT), autonomous vehicles, and next-generation networking infrastructures has significantly increased the demand for intelligent, adaptive, and decentralized communication frameworks. Traditional communication systems and conventional routing protocols are no longer sufficient to manage the challenges associated with highly dynamic wireless environments such as Mobile Ad Hoc Networks (MANETs) and Vehicular Ad Hoc Networks (VANETs). Frequent topology changes, high node mobility, routing instability, communication delay, congestion, packet loss, scalability limitations, and security vulnerabilities greatly affect communication reliability and Quality of Service in modern mobile communication networks.

The proposed research on "Multi-Agent AI Systems for Cooperative Communication in Hybrid MANET-VANET Architectures" addresses these challenges by integrating Artificial Intelligence, Multi-Agent Systems, Machine Learning, and adaptive communication mechanisms into a unified hybrid communication framework. The hybrid architecture combines the flexibility of MANETs with the intelligent vehicular communication capabilities of VANETs to create a scalable, decentralized, and cooperative communication environment capable of supporting next-generation intelligent networking applications.

## 12. FUTURE SCOPE

The proposed research on Multi-Agent AI Systems for Cooperative Communication in Hybrid MANET-VANET Architectures provides a strong foundation for future advancements in intelligent wireless communication systems. Although the proposed framework addresses many limitations of traditional communication architectures, several research opportunities and technological improvements remain open for future exploration.

## REFERENCE

1. Hota, L., Nayak, B. P., & Kumar, A. (2024). Machine learning algorithms for optimization and intelligence in wireless networks: WSNs, MANETs, VANETs, and USNs. In 5G and Beyond Wireless Communications (pp. 306-332). CRC Press.
2. Naeem, M. A., Ullah, R., Chudhary, S., & Meng, Y. (2025). A critical analysis of cooperative caching in ad hoc wireless communication technologies: current challenges and future directions. Sensors, 25(4), 1258.
3. Lashari, H., Ali, H. M., & Laghari, A. (2020). Uav communication networks issues: A review. Arch. Comput. Methods Eng, 3.
4. Ifourah, Y., Pouyap, L. T., Boudjit, S., Bouzefrane, S., Balla, A., & Boussaha, R. (2025, June). Towards a Secure Modular Drone-Based Hardware Architecture for IoT-Enabled Traffic Safety in Intelligent Transportation Systems. In 2025 12th IFIP International Conference on New Technologies, Mobility and Security (NTMS) (pp. 43-50). IEEE.
5. Shankar, A., Dayalan, R., Chakraborty, C., Dhasarathan, C., & Kumar, M. (2025). A modified social spider algorithm for an efficient data dissemination in VANET. Environment, Development and Sustainability, 27(10), 24659-24702.
6. Qiu, X., Xie, Y., Wang, Y., Ye, L., & Yang, Y. (2021). QLGR: A Q-learning-based Geographic FANET Routing Algorithm Based on Multiagent Reinforcement Learning. KSII Transactions on Internet & Information Systems, 15(11).
7. Jamil, M., Haider, U., Khan, I. U., & Bhatia, T. K. (2024). Intelligent transportation systems for IoT-based UAV networks. In Cyber Security for Next-Generation Computing Technologies (pp. 231-252). CRC Press.

8. Luo, J., Wang, Z., Xia, M., Wu, L., Tian, Y., & Chen, Y. (2023). Path planning for UAV communication networks: Related technologies, solutions, and opportunities. ACM Computing Surveys, 55(9), 1-37.
9. Jahan, F., Devore, J., Niyaz, Q., & Sun, W. (2026). Application of non-cooperative game theory in analyzing a potential DoS on autonomous vehicular network. Simulation, 102(4), 277-299.
10. Almutairi, R. M. (2025). IoT-Enhanced Vehicular Networks: Simulation Frameworks for Energy Efficiency and Cyber-Security in Smart Cities (Doctoral dissertation, Newcastle University).
11. Mishra, R. (2024). Raspberry Pi Performance analysis across its Operating System in LED Control Operation. International Journal of Advanced Research and Multidisciplinary Trends (IJARMT), 1(2), 01-11.
12. Mishra, R. (2025). IOT and DSP (combination of hardcore Virtex-5 FPGA and soft core DSP processor) OFDM System PAPR Reduction Using Artificial Intelligence Algorithm. International Journal of Advanced Research and Multidisciplinary Trends (IJARMT), 2(1), 135-149.
13. Mishra, R., & Sharma, A. (2026). Enhanced Trajectory Tracking of a 6-DOF Robotic Manipulator Using GA–PID and ANN–PID Controllers. International Journal of Research & Technology, 14(2), 53-70.