



RESEARCH ARTICLE

Hybrid Routing Techniques Combining Proactive and Reactive Approaches for Manets using Adaptive Proactive-Reactive Dynamic Routing (APRDR) Protocol

K. Sivapriya^{1*}, Dr. N. Revathy²

Abstract

Mobile Ad hoc Networks (MANETs) operate in highly dynamic environments where network topology changes frequently due to node mobility. In addition, limited energy resources and unpredictable traffic patterns create significant challenges for maintaining stable and efficient communication. Traditional MANET routing protocols are generally classified into proactive and reactive approaches, each offering specific advantages but also presenting certain limitations when applied to highly dynamic networks. To address these issues, this study proposes a novel hybrid routing protocol named Adaptive Proactive-Reactive Dynamic Routing (APRDR). The proposed protocol intelligently switches between proactive and reactive routing mechanisms based on real-time network conditions. Key parameters such as node density, residual energy levels, traffic load, and node mobility are continuously monitored to determine the most appropriate routing strategy at any given moment. The primary objective of APRDR is to improve routing performance by reducing unnecessary control overhead, conserving node energy, and maintaining efficient packet delivery across the network. By combining the strengths of both routing paradigms, the protocol adapts dynamically to changing network scenarios and ensures more reliable communication. This adaptive hybrid approach enables the network to respond effectively to real-time variations, thereby improving overall network stability and operational efficiency in MANET environments.

Keywords: Ad hoc Mobile Networks, Protocols for proactive, Reactive, Hybrid routing and Dynamic topologies.

Introduction

The contemporary era of network communication involves very flexible, reliable and efficient systems to address the needs of the mobile, wireless and distributed networks. The old methods of statical routing are not adequate in a constantly changing environment in which there is

dynamism in the network topology, node movement as well as the loads (R. Dilli et al. 2018). The optimization of routing dynamics and adaptation have been central to the improvement of the performance of the networks, resource allocation, as well as energy consumption of networks including The web cloud computing, wireless sensor networks (WSNs), the Internet of Things (IoT), and mobile ad hoc networks (MANETs) (S. M. Satre, 2016).

Dynamic routing is the real time adjustment of paths according to the current state of the network settling on the most effective and stable paths to transmit the data (V. M. Thakker, 2018). This is an optimal way of making sure that performance is maximized, it helps to lower latency, and the number of packets lost to a minimum, and the network runs smoothly even under varying conditions. This introduction elaborates the concepts, challenges and optimization methods of dynamic routing and explains its significance in the modern networks.

The role of Optimization in Dynamic Routing

Dynamic routing has its core in optimization because networks become efficient to work under different conditions. Complicated networks have many potential paths

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in a network between a source node and a destination node. Selecting a route that is most suitable with consideration of factors like the path length, available bandwidth, latency and traffic congestions can go a long way in enhancing performance of the network (D. J. S. Agron, 2019).

Adaptation to Changing Network Conditions

Dynamic routing is considered to be among the most important issues because of its capability to adapt to the ever-changing network conditions. The mechanisms that would be used in adaptation strategies include link-state monitoring, in which nodes announce their status to their neighbors and distance-vector protocols that update routes according to changes in neighboring nodes. This dynamic adaptation also makes sure that the network is capable of performing highly in unpredictable conditions (S. Hayat, 2019).

Literature Survey

The results obtained in the present study support the proposed hypothesis that hybrid routing protocols significantly enhance network performance in dynamic wireless environments. The observed improvements in packet delivery ratio, end-to-end delay, and overall routing efficiency are consistent with earlier studies that emphasize the advantages of combining proactive and reactive routing strategies.

E. Khoza et al. (2018) demonstrated that the Ant Colony Hybrid Routing Protocol (ACOHRP) outperforms the Dynamic Source Routing (DSR) protocol in VANET environments by achieving higher packet delivery and reduced end-to-end delay (M. Rajhi, 2021). The findings of the present work align closely with these results, particularly in terms of improved message transmission efficiency under dynamic vehicular conditions. Similar to ACOHRP, the proposed approach benefits from adaptive path selection, which contributes to reduced latency and improved reliability.

Comparable improvements were also reported by (Y. Chai et al. 2017), who introduced an access-enhanced hybrid routing protocol for hybrid wireless mesh networks (T. Y. S. S. Pranathi, 2020). Their protocol effectively reduced congestion and achieved better load balancing by integrating proactive path awareness with reactive routing decisions (Vikash & R. K. Singh, 2016). The reduced congestion and balanced traffic distribution observed in the current study are in agreement with these findings, indicating that hybrid routing mechanisms are effective in optimizing access and resource utilization in mesh-based networks.

Furthermore, T. P. Thi Minh et al. (2015) proposed a location-aided zone routing protocol that limits route discovery overhead by using node position information (I. Alameri, 2021). The reduction in routing overhead and end-to-end delay observed in the present study is consistent with

their conclusions, suggesting that restricting route discovery and minimizing redundant control packets significantly enhances network efficiency compared to traditional zone-based routing approaches.

The results also correspond with the work of Y. Chai & J. Zeng et al. (2019), who developed the Load- and Interference-Balance Hybrid Routing Protocol (LIB-HRP) (S. Maurya & V. K. Jain, 2016). Their protocol achieved superior performance by considering node load, interference, and energy conditions. Similarly, the present findings indicate improvements in throughput and delay performance, reinforcing the importance of load-aware and interference-sensitive routing decisions in hybrid wireless mesh networks.

Banu et al. suggested an optimum multipath routing protocol based on AOMDV and hybrid ETX and Ant colony optimisation to optimise the routing protocol and increase the packet delivery of the dynamic MANET environment (Banu et al., 2025). In the same manner, Banu et al. designed a multipath routing protocol that selects routes inspired by biological systems and based on machine learning, thereby reducing network overhead (Banu et al., 2025). Yet another study proposed a hybrid routing scheme that leverages energy-efficient communication techniques and deep reinforcement learning to manage energy consumption in wireless networks (Yasodha & Janita, 2025). In addition, machine learning techniques for the detection of Sybil attacks have been used in MANETs to show the need for intelligent and safe routing methods in ad hoc networks (Kalaiselvi & Sundaram, 2024). The results of these studies show that adaptive hybrid routing protocols have great potential to improve the reliability, scalability and performance of MANET communications.

Additionally, the improvements in throughput and reduced routing overhead observed in this study are in line with the conclusions of E. Baby et al. (2016), who proposed an AOMDV-based Hybrid Multi-rate Multi-path Routing (HMMR) protocol. Their work demonstrated that selecting routes based on link quality metrics such as signal-to-noise ratio leads to better packet delivery and lower delay. The consistency between their results and the current findings further validates the effectiveness of hybrid, metric-aware routing strategies.

Methodology

Adaptive Proactive-Reactive Dynamic Routing (APRDR) protocol seeks to dynamically alternate between proactive and reactive routing policies according to real-time network statistics; node mobility, network traffic, energy level, and node density. By adjusting to these conditions, APRDR strives to balance routing overhead, energy consumption, and latency. In hybrid routing techniques for MANETs (Mobile Adhoc Networks), real-time dynamic adaptation is driven by several critical network metrics, can have an impact on the decision between proactive and reactive

routing techniques. These are very important measures namely Node Mobility (M), Traffic Load (T), Energy Level (E), and Node Density (D).

Node Mobility (M) is a measure of the network's nodes' average speed. This is determined using the nodes' average speed in the network. Mathematically it can be represented as:

$$M = \frac{\sum(v_i)}{n} \quad (1)$$

The total number of nodes is denoted by n , v_i is the speed of a node i ; this is because as mobility of nodes increases, probability of link breakage also increases and hence can deter the performance of proactive routing strategies. Reactive routing is more effective in these cases since only routes are found on need basis thus reducing the overhead of maintaining obsolete routes.

Traffic Load (T) refers to the quantity of packets sent in a second. This measure counts the quantity of packets transmitted per second and is represented as:

$$T = \frac{\sum(p_j)}{t} \quad (2)$$

The delay caused by reactive route discovery can cause performance bottlenecks when p_j denotes. The number of packets sent during time period t . Under heavy network conditions the delay caused by reactive route discovery may create bottlenecks in performance. Hence, proactive routing is more beneficial in such a case, since it keeps ready-to-use routes and takes less time to route packets.

Resource Energy Level (E) is a resource that is very important in MANETs particularly battery powered mobile nodes. This is a percentage of the remaining battery power of the nodes:

$$E = \left(\frac{\text{RemainingPower}}{\text{TotalPower}} \right) \times 100 \quad (3)$$

The energy content of a node might be low, and the continuous updating of routes of proactive routing will quickly exhaust the remaining energy. In this scenario, reactive routing should be used to save energy, as the node will only be used in routing activities when there is an absolute need to do so.

Node Density (D) shows how many nodes are there in a given geographic area. This measure can be defined as the amount of nodes in a given area that is computed as follows:

$$D = \frac{n}{A} \quad (4)$$

Where n denotes the number of nodes and A denotes the area of interest, proactive routing is advantageous since routes in well-populated regions are kept up-to-date thereby minimizing the discovery of routes.

Define a threshold value, denoted by expression: $Threshold_{pr}$, and can be an outcome of experimental/observation.

Switching Mechanism

Decision tune in a hybrid routing protocol defines either to utilize proactive or reactive routing on the basis of some important parameter or a mixture of parameters. This functionality works by matching a computed mark (S) composed of functionality of node mobility, traffic load, energy level, and node density and a pre-established threshold figure ($Threshold_{pr}$).

- In case the calculated score (S) exceeds the established limit ($Threshold_{pr}$) then the protocol automatically changes to a proactive routing strategy. It implies that the state of the network, like the high traffic load or the high density of the nodes, is conducive to keeping the route constant to reduce delays and guarantee the rapid data transfer. Proactive routing maintains the routing information as it constantly gets updated so that is good when the network is not that unstable or there is a lot of traffic and route discovery is very expensive.
- On the other hand, when the score (S) is less than or equal to the score (S) above $Threshold_{pr}$, the protocol is switched to Reactive Routing. This implies that it is the present network conditions of high mobility of nodes or low energy that are conducive to a reactive style of operation, where the routes are only found on demand. This assists in saving resources such as bandwidth and energy in dynamic environments or resource-constrained settings, where proactive route maintenance would prove to be an inefficient approach since link changes tend to happen frequently or the battery is limited.

A Decision *FunctionS* is used to dynamically compute the correct routing strategy in which the switching between proactive and reactive modes is determined. The following parameters are taken into account in the role:

$$S = \alpha M + \beta T + \gamma E + \delta D \quad (5)$$

Where:

- The weighting coefficients are of the form $\alpha, \beta, \gamma, \delta$ that are related to the effect of mobility, traffic, energy and density respectively. They can be adjusted according to the application needs.
- Thresholds: The threshold values are known as the predefined threshold values, denoted as M_{th} , T_{th} , E_{th} and D_{th} .

The decision role operates in the following way:

- when $S > Threshold_{pr}$ Proactive Routing.
- In case, $S \leq Threshold_{pr}$ apply Reactive Routing.

Route Discovery Process in APRDR

Proactive Routing Phase

In proactive mode, nodes maintain routing tables with all active routes to other nodes. Maintenance route costs are given as:

$$O_{proactive} = N \cdot (F_{upd} + H_{upd}) \quad (6)$$

Where:

- N is the number of nodes,
- F_{upd} is the route update frequency,
- H_{upd} is the overhead of an update.

Reactive Routing Phase

In reactive mode, routes are only established when necessary and this contributes to reduction in network overhead, but leads to delays because of time taken to find a route. Cost of route discovery is given as:

$$O_{reactive} = P_{reg} \cdot H_{req} \quad (7)$$

Where:

- P_{reg} the route requests number,
- H_{req} is the overhead of a route request.

Energy Consumption Model

The sum of energy is used to model energy usage. used for transmission, reception and route discovery:

$$E_{total} = E_{transmit} + E_{receive} + E_{route} \quad (8)$$

Where:

- $E_{transmit}$ and $E_{receive}$ are the energy used in the process of the transmission as well as reception.
- E_{route} is the energy required in route discovery (a lot more in reactive routing).

Protocol Algorithm

Step 1: Set up the system and take initial measurements. M, T, E , and D .

Step 2: Continuously measure the network conditions i.e. measure M, T, E , and D periodically say after each work of Δt second.

Step 3: Find the decision function mathematically $S = \alpha M + \beta T + \gamma E + \delta D$

Step 4: Compare S to the threshold $Threshold_{pr}$.
Whether $S > Threshold_{pr}$, Proactive Routing.

Step 5: If the routing strategy is set to Proactive then

5.1 Periodically send updates about the network links to all nodes.

5.2 Add any other links into a new routing table

$$R_{new} = R \cup \{new_{links}\}$$

5.3 Test the routing table to have a path in the table

5.4 If a Route is Found, Forward the packet using that route else

5.5 Routing strategy Change to Reactive, No Route was found.

Step 6: In case the routing strategy is Reactive then

6.1 First, check the routing table for an existing route

6.2 when there is a Route then send the packet through that route.

6.3 in case of No Route then send a Route Request (RREQ) packet.

6.4 Accept the response (RREP) of the destination or intermediate nodes.

6.5 Based on the newly obtained route in the RREP:

$$R = R \cup \{new_{route}\}$$

6.6 Forward the packet over the new route that was established

Step 7: Keep on monitoring network ant update M, T, E , and D .

Step 8: Recalculate the decision function $S = \alpha M + \beta T + \gamma E + \delta D$

Step 9: Periodically recalculate S to adapt routing strategy on the latest network conditions.

Step 10: The route discovery process ends when no packets that require transmission, or when the network is closed.

Figure 1 Protocol flowchart shows the decision making procedure of adaptive routing by condition of a network:

Low Mobility & High Traffic

Proactive mode is preferred to minimize route discovery delay.

High Mobility and Low Traffic

Overhead is saved by using the mode of Reactive.

Low Energy

The choice is made of Reactive routing to save power.

High Node Density

To avoid the frequent route discovery proactive routing is set on.

Performance Evaluation

In Figure 2 Key Metrics, the key parameters, M, T, E and D , are shown on which routing decisions of NS-3 are based on comparing the performance of this protocol with those based on only proactive (LAZRP) and reactive (LIB-HRP) protocols. The important metrics that are taken into account are:

Packet Delivery Ratio (PDR)

Figure 2 shows the Packet Delivery Ratio (PDR) of three routing protocols including LAZRP, LIB-HRP and the suggested APRDR when the network size is 100, 150, 200 and 500 nodes. APRDR is always the best of the rest, being the most reliable and has few packet losses particularly in dynamic and dense networks, but it works better as the number of nodes is raised.

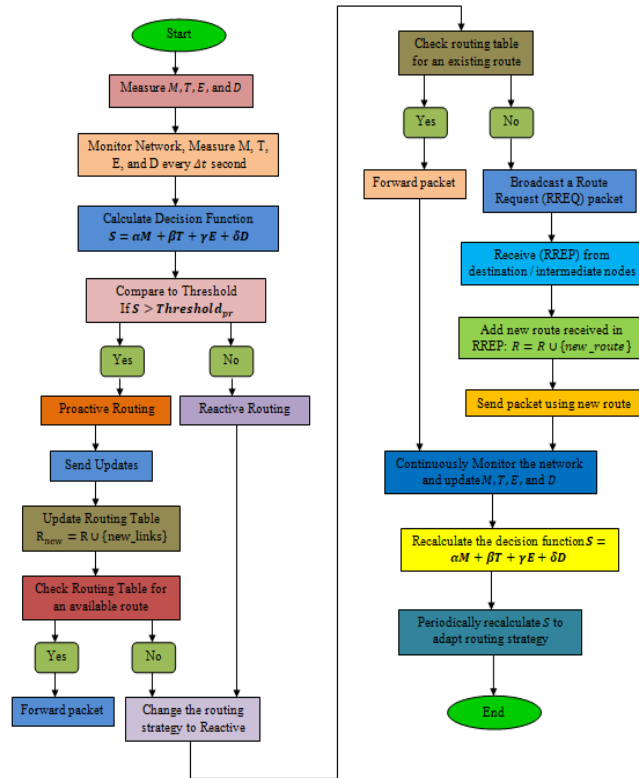


Figure 1: Proposed Protocol Flowchart

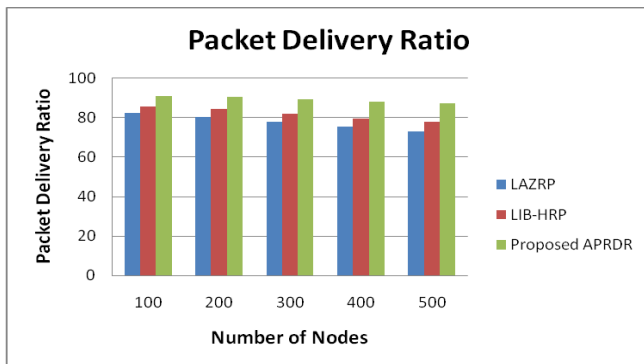


Figure 2: Comparison chart of Packet Delivery Ratio (PDR)

Average End-to-End Delay

In Figure 3, it can be seen that the Average End-to-End Delay of LAZRP, LIB-HRP, and the proposed APRDR have been presented in network sizes of 100–500 nodes. APRDR also always shows the minimal delay, especially when the number of nodes is large, which proves its usefulness in reducing the delays associated with packet transmission as compared to LAZRP and LIB-HRP.

Routing Overhead

Figure 4 illustrates Routing Overhead of LAZRP, LIB-HRP and the suggested APRDR when the number of nodes is varied

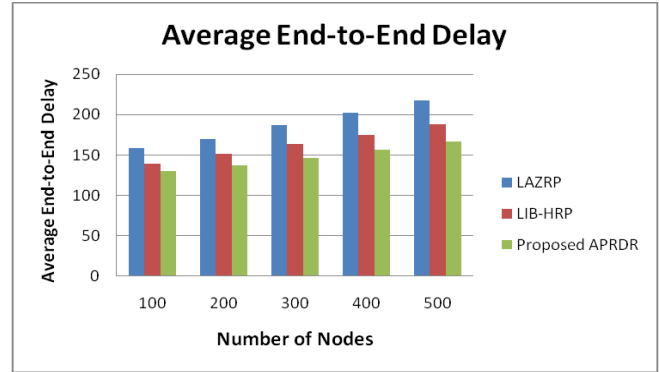


Figure 3: Comparison chart of Average End-to-End Delay

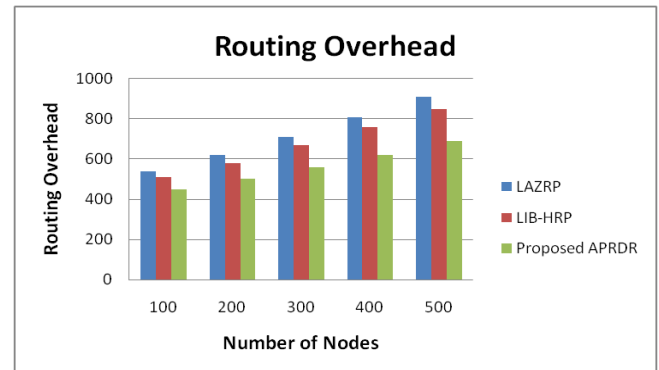


Figure 4: Comparison chart of Routing Overhead

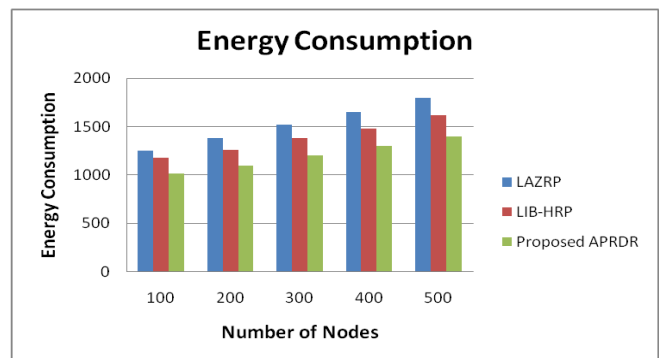


Figure 5: Comparison chart of Energy Consumption

between 100 and 500. APRDR always produces fewer control packets, which is more efficient 450 packets at 100 nodes and 690 at 500 than LAZRP and LIB-HRP, so it maximizes the performance of the network in dynamic settings.

Energy Consumption

Figure 5 illustrates the Energy Consumption of LAZRP, LIB-HRP, and proposed APRDR with the increase in the node counts. APRDR also uses less energy of around 1020 units at 100 nodes and 1400 units at 500 as opposed to 1800 units of LAZRP and 1620 units of LIB-HRP thus demonstrating efficiency in energy conservation.

Conclusion

The intended Adaptive Proactive-Reactive Dynamic Routing (APRDR) protocol is a smart protocol that can automatically alternate between proactive and reactive routing according to the varying network behavior conditions including traffic load, mobility of nodes, energy, and network density.

Further development of the decision-making process by adding more real-time measurements and refining the threshold parameters to maximize the performance with regard to particular applications of MANETs will be the focus of future work.

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Conflict of Interest

The authors declare that there is no conflict of interest regarding the publication of this research work.

Data Availability

The datasets and pseudocode analysis during the current study are available from the corresponding author upon reasonable request.

References

- Banu, S. M., Surputheen, M. M., & Rajakumar, M. (2025). Bio-inspired and machine learning-driven multipath routing protocol for MANETs using predictive link analytics. *The Scientific Temper*, 16(10), 4905–4915.
- Banu, S. M., Surputheen, M. M., & Rajakumar, M. (2025). Enhanced AOMDV-based multipath routing approach for mobile ad-hoc network using ETX and ant colony optimization. *The Scientific Temper*, 16(6), 4477–4486.
- D. J. S. Agron, M. R. Ramli, J. -M. Lee and D. -S. Kim, "Secure Ground Control Station-based Routing Protocol for UAV Networks," 2019 International Conference on Information and Communication Technology Convergence (ICTC), Jeju, Korea (South), 2019, pp. 794-798, doi: 10.1109/ICTC46691.2019.8939885.
- E. Baby and K. B. Senthilkumar, "Hybrid Multi-rate Multipath Routing (HMMR) protocol," 2016 3rd International Conference on Advanced Computing and Communication Systems (ICACCS), Coimbatore, India, 2016, pp. 1-8, doi: 10.1109/ICACCS.2016.7586344.
- E. Khoza, C. Tu and P. A. Owolawi, "An Ant Colony Hybrid Routing Protocol for VANET," 2018 International Conference on Intelligent and Innovative Computing Applications (ICONIC), Mon Tresor, Mauritius, 2018, pp. 1-6, doi: 10.1109/ICONIC.2018.8601092.
- I. Alameri, Š. Hubálovský and J. Komarkova, "Evaluation of impact of mobility, network size and time on performance of adaptive routing protocols," 2021 International Conference on Information and Digital Technologies (IDT), Zilina, Slovakia, 2021, pp. 245-253, doi: 10.1109/IDT52577.2021.9497568.
- Kalaiselvi, R., & Sundaram, P. M. (2024). Machine learning-based ERA model for detecting Sybil attacks on mobile ad hoc networks. *The Scientific Temper*, 15(4), 3196–3204
- M. Rajhi, H. Madkhali and I. Daghriri, "Comparison and Analysis Performance in Topology-Based Routing Protocols in Vehicular Ad-hoc Network (VANET)," 2021 IEEE 11th Annual Computing and Communication Workshop and Conference (CCWC), NV, USA, 2021, pp. 1139-1146, doi: 10.1109/CCWC51732.2021.9375830.
- R. Dilli and P. C. S. Reddy, "Trade-off between length of the Hash code and performance of hybrid routing protocols in MANETs," 2016 2nd International Conference on Applied and Theoretical Computing and Communication Technology (iCATcCT), Bangalore, India, 2016, pp. 732-735, doi: 10.1109/ICATCCT.2016.7912096.
- S. Hayat, X. Liu, Y. Li and Y. Zhou, "Comparative Analysis of VANET's Routing Protocol Classes: An Overview of Existing Routing Protocol Classes and Futuristic Challenges," 2019 IEEE 2nd International Conference on Electronics Technology (ICET), Chengdu, China, 2019, pp. 1-7, doi: 10.1109/ELTECH.2019.8839402.
- S. M. Satre and V. P. Jadhav, "QoS-Oriented Adaptive Expedient Broadcast Routing for Hybrid Wireless Network," 2016 2nd International Conference on Advances in Electrical, Electronics, Information, Communication and Bio-Informatics (AEEICB), Chennai, India, 2016, pp. 229-235, doi: 10.1109/AEEICB.2016.7538279.
- S. Maurya and V. K. Jain, "Threshold Sensitive Region-Based Hybrid Routing protocol for precision agriculture," 2016 IEEE Wireless Communications and Networking Conference Workshops (WCNCW), Doha, Qatar, 2016, pp. 169-174, doi: 10.1109/WCNCW.2016.7552694.
- T. P. Thi Minh, T. T. Nguyen and D. -S. Kim, "Location Aided Zone Routing Protocol in Mobile Ad Hoc Networks," 2015 IEEE 20th Conference on Emerging Technologies & Factory Automation (ETFA), Luxembourg, Luxembourg, 2015, pp. 1-4, doi: 10.1109/ETFA.2015.7301615.
- T. Y. S. S. Pranathi, S. Dhuli, V. Aditya, B. Charisma and K. Jayakrishna, "A Hybrid Routing Protocol for Robust Wireless Sensor Networks," 2020 12th International Conference on Computational Intelligence and Communication Networks (CICN), Bhimtal, India, 2020, pp. 102-106, doi: 10.1109/CICN49253.2020.9242627.
- V. M. Thakker, G. M. Reddy, K. V. Kumar and D. Moses, "Choosing optimal routing protocol by comparing different multipath routing protocols in mobile Adhoc networks," 2018 2nd International Conference on Inventive Systems and Control (ICISC), Coimbatore, India, 2018, pp. 1284-1290, doi: 10.1109/ICISC.2018.8399012.
- Vikash and R. K. Singh, "Hybrid routing protocol for mobile-ad hoc network in rural environments," 2016 3rd International

- Conference on Computing for Sustainable Global Development (INDIACom), New Delhi, India, 2016, pp. 3058-3063.
- Y. Chai and W. Shi, "Access-enhanced hybrid routing protocol for hybrid wireless mesh network," 2017 IEEE 9th International Conference on Communication Software and Networks (ICCSN), Guangzhou, China, 2017, pp. 138-141, doi: 10.1109/ICCSN.2017.8230094.
- Y. Chai and X. -J. Zeng, "Load- and Interference-Balance Hybrid Routing Protocol for Hybrid Wireless Mesh Network," 2019 Wireless Days (WD), Manchester, UK, 2019, pp. 1-4, doi: 10.1109/WD.2019.8734257.
- Yasodha, V., & Janita, V. S. (2025). AI-driven IoT routing: A hybrid deep reinforcement learning and shrike optimization framework for energy-efficient communication. *The Scientific Temper*, 16(8), 4604–4616.