International Journal of Advanced Computer Technology
ISSN: 2319-7900 www.ijact.org Volume 12, Issue 5, September-October 2023

Energy and Load Aware Multipath Route Selection for Mobile Ad hoc Networks

Surbhi Rani, Vivek Sharma
Computer Science and Engineering,
Technocrats Institute of Technology, Bhopal, Madhya Pradesh, India
Emails: Surabhishrivastava682@gmail.com, sharma.vivek95@yahoo.in

Abstract— *Routing protocols are crucial in delivering packets from source to destination in scenarios where destinations are not directly within the sender's range. Various routing protocols employ different strategies, but their presence is indispensable for seamless data transfer from source to destination. Multipath routing, while offering load balancing, often falls short in efficiently distributing the network's load, thus adversely impacting the vital communication resource—energy—due to packet loss. This paper introduces an Energy-Efficient Load-Aware Routing (ELAM) scheme to enhance the routing performance of Mobile Ad hoc Networks (MANETs). Our motivation stems from the observation that many multipath routing protocols are designed based on a single criterion, such as the shortest path, often neglecting load balancing or energy conservation. While the Ad Hoc On-Demand Multipath Distance Vector (AOMDV) protocol demonstrates improved performance compared to unipath routing schemes, achieving both load balancing and energy efficiency remains challenging.*

The proposed ELAM scheme considers energy conservation, the shortest path, and load balancing to enhance the performance of multipath routing protocols. ELAM considers the shortest path and energy conservation while accommodating more than two paths in a MANET. We introduce an energy factor that contributes to the network's lifespan, with efficient load balancing enhancing the longevity of nodes and the overall network. The energy factor provides insights into the energy status, and we evaluate the performance of AODV, AOMDV, and the proposed ELAM. The results demonstrate that the proposed scheme outperforms existing protocols and effectively manages unnecessary energy consumption by mobile nodes. Our performance analysis reveals a minimum 5% improvement in throughput and Packet Delivery Ratio (PDR), indicating reduced packet dropping and network delays.

Keywords: ELAM, Energy, Load Balancing, Multipath, MANET, Routing.

I. INTRODUCTION

A potential approach to facilitate communication is the utilisation of Mobile Ad Hoc Networks (MANETs), which are flexible, self-contained cellular networks that can be easily deployed and adapted without the need for infrastructure support or centralised administration [1]. In MANETs, mobile nodes can move from one location to another, establishing connections with each other without relying on centralised management. These nodes collaborate in transmitting data over multiple hops, utilising a shared direct access channel designed for user-friendly operation. Each node in a MANET serves as both a host and a router and in networks with a high degree of autonomy, devices are free to move independently and connect or disconnect from other nodes as needed. Every node must function as a router to route traffic, even if it doesn't concern them directly. Routing in MANETs has proven to be a challenge, primarily due to the extensive mobility of the nodes, resulting in a dynamic network topology. Various routing techniques have been developed to address this challenge.

Routing guides packets with logical addresses from their source to their final destination by passing through intermediary nodes in packet-switched networks. In highly mobile ad hoc networks, packets between nodes are routed by the MANET routing protocol, which can be a set of rules or behaviours. Ad hoc mobile networks may employ a variety of routing techniques.

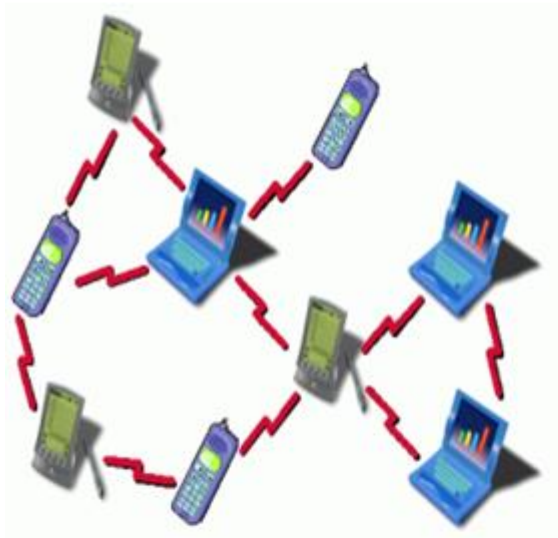

Figure 1: Mobile Ad-Hoc Networks

Nodes establish routes and maintain them as needed in these networks. Intermediate nodes may discard packets if no alternative route to the destination is available, resulting in frequent route disruptions. This can lead to reduced throughput and disrupted communication. Additionally, identifying new routes in areas with high node mobility becomes necessary, increasing the average end-to-end delay. To address these challenges, multi-route protocols [2] identify and cache multiple routes discovered during the route discovery process. This approach helps mitigate connection errors on the primary path by switching to an alternate route without initiating route discovery unless all previously established routes are unavailable. The geographical coordinates obtained and utilised during route calculations, closely tied to location data, play a crucial role in this context.

II. LITERATURE SURVEY

In the realm of Mobile Ad Hoc Networks (MANETs), researchers have delved into the intricacies of energy-efficient and load-balanced routing, exploring various factors that influence these critical aspects. Notable studies have examined multipath routing, link capacity-based approaches, queuing techniques, enhanced routing strategies, and path reliability in MANETs. One significant work by Deepak Sharma and colleagues [1] evaluated MANET performance under varying transmission power and node configurations using the Ad-hoc On-Demand Multipath Distance Vector (AOMDV) Routing Protocol. Sudhir K and others [3] explored routing strategies based on reinforcement learning for scenarios with dynamic node positions, demonstrating how reinforcement learning algorithms can adapt to network changes and optimise packet delivery times. Kumar P and team [4] highlighted the efficiency of location-based packet forwarding, advocating it as a method with reduced processing overhead.

Additionally, Obaidat M et al. [5] introduced a single-route variant of the AODV routing protocol to address challenges related to estimating journey duration. They proposed a mechanism for creating unique paths that minimise time. Kashyap I and collaborators [6] developed the Location-Based Multipath Routing Protocol (Location-BMP), specifically tailored for non-overlapping node positions, allowing for selecting route nodes based on geographical information. Arora N et al. [7] presented the Adaptive Geographic Location Routing (GLAAR) protocol, simplifying computational complexity by selecting the most efficient packet transmission path based on GPS-derived location information. Abdoos M et al. [8] enhanced the “Greedy” routing protocol with the “MRF” routing protocol, utilising a combination of speed, power, and distance metrics to improve packet forwarding efficiency and reduce losses.

Moreover, Sultanuddin S et al. [9] introduced the Secure Routing Multipath Routing (STMR) protocol, which integrates clustering and optimal route selection using a balanced set triangle optimisation technique and a multiple-choice algorithm. Sungwook K et al. [10] proposed a routing strategy based on simulated annealing pathways, allowing nodes to dynamically select routes to manage traffic in mobile ad hoc networks. Wacheb et al. [11] developed the Multi-Criteria Node Range Metric (MCNR) for node allocation, factoring in parameters such as node lifetime, speed, battery life, and queue length to determine suitable paths.

Swetha M and Kolab [12] presented the Strong Secure Mysterious Location Routing (S2MLBR) protocol, which segments the network into sectors using Optimal Military Jerk Separation (OTW) and employs host factors like signal strength and mobility to determine data transfer sectors. This protocol also addresses the optimal reliability problem and selects the most trustworthy nodes as intermediaries. Ashish Bagwari and team [13] conducted a study

ISSN: 2319-7900 www.ijact.org Volume 12, Issue 5, September-October 2023

investigating the performance of the AODV routing protocol in response to an increasing number of nodes in MANETs. Their findings suggested that AODV performed well in terms of throughput, end-to-end delay, and data dropout rates in these scenarios. Lastly, Vishnu Kumar Sharma and colleagues [14] proposed a "Mobile Agent-Based Congestion Control Using AODV Routing Protocol Technique for Mobile Ad-Hoc Network," which leverages mobile agents to gather congestion data and dynamically modify routing tables, effectively mitigating network congestion.

III. PROPOSED ELAM APPROACH

In the preceding related work, like certain academic endeavours that exclusively address load balancing in Mobile Ad Hoc Networks (MANETs), we observed that each aspect operates as an independent module. To enhance overall performance, we present the problem statement "Multipath Routing Backbones for Load Balancing in Mobile Ad Hoc Networks" and analyse network behaviour based on parameters like throughput, packet delivery ratio, routing overhead, and end-to-end delay. In comparisons between AOMDV and AODV, AOMDV exhibits lower reliability. Given MANET's dynamic nature, dynamic topology generation poses significant challenges, including energy consumption, data loss, and efficient load balancing. As computational capabilities and processing power vary among nodes, some may be underutilised while others are overburdened, potentially leading to load imbalances. It's presumed that nodes with high processing power will experience lower or negligible loads most of the time due to rapid task completion. Thus, the presence of overloaded nodes alongside underutilised nodes is undesirable. Additionally, routing packet broadcasts increase routing overhead whenever a link is lost. To mitigate this, we employ multipath routing techniques to minimise overhead and balance loads to maximise data delivery.

The existing protocol offers multipath route discovery and path maintenance methods based on a cumulative metric value derived solely from signal strength between two nodes within a path. This metric solely evaluates the current path's link strength, and path longevity relies solely on the remaining energy of the nodes, disregarding node behaviour and energy consistency, making it unsuitable for highly mobile heterogeneous MANETs.

Effective routing in a MANET necessitates the even distribution of routing tasks among mobile hosts using the routing protocol. Imbalanced traffic and load distribution adversely affect network performance, leading to some nodes bearing a disproportionate routing workload, resulting in large queue sizes, increased packet delays, higher packet loss rates, and greater power consumption. The ELAR approach introduces a solution for load-aware and energy-efficient routing in MANETs. It offers advantages such as optimal resource utilisation, increased throughput, and reduced route overload. Load balancing is achieved by adjusting path costs, ensuring the load is distributed unevenly across various links.

MANETs are characterised by mobile hosts equipped with wireless communication capabilities. Key features of MANETs include the absence of a central coordinator, rapid deployment, self-configuration, multi-hop radio communication, frequent link disruptions due to mobile nodes, and resource constraints (bandwidth, processing power, battery life, etc.). Additionally, all nodes in MANETs are mobile, leading to a highly dynamic topology. Consequently, routing protocols for MANETs must be flexible enough to adapt to frequent topology changes, provide Quality of Service (QoS), maintain a low collision rate, be computationally efficient, and offer optimal and loop-free paths. Leveraging the AOMDV protocol at each node with a dynamic queue length, we achieve load balancing through energy-awareness. This approach results in fewer packet drops, reduced routing overhead, increased throughput, and higher packet delivery ratios.

Algorithm: Energy & Load Aware based Multipath Route Selection for MANET (ELAM)

1. Initialise:
- Mm = Mobile Node's Set // where m = 0, 1, 2, ...
- Configure sender (Sj) and receiver (Rj) nodes.
2. Routing protocol used = AOMDV.
3. Set Initial Energy:
- Ei // Different energy values exist for each node (M).
4. Broadcasting Path:
Upon finding a path from Sj to Rj (for j = 0, 1, 2, ..., n-1):
{
Check the route's number.
If (route ≥ 1):

```
    {
      // There are alternate routes in the network.
      Find (each route's energy && energy > 0).
      Choose three paths as the shortest paths.
      Route: send acknowledgements for all possible routes.
    }
    Else If (route == 1):
    {
      // Select only one path for data sending.
    }
    Else:
    {
      //route is unreachable.
    }
  }

6. Send information along the chosen route.

7. //Xx Processing capability of the executed route // Xxy Processing capability of all existing routes.

8. Data_send (Sj, Rj, data):
  // Sending data with minimal drop.
  {
    9. The sender sends data through the computed path.

    10. Check the link capacity of Im and Im+1 nodes:
    {
      // Link capacity between intermediate nodes.
      If (Capacity == Full):
      {
        // Reduce data rate and forward all stored incoming data.
      }
      Else:
      {
        The receiver receives data from the Ix node.
        Send ACK to sender Sj.
      }
    }
  }
12. Exit.
```

Due to the critical importance of preserving network longevity and minimising energy consumption, we consider the remaining battery life of neighbouring nodes when selecting from multiple available routes. To achieve this, each node must communicate its current energy status to its neighbours. We normalise the current energy levels using the maximum battery capacity, scaling them up to 100 joules or setting them as required. ELAM considers all potential future hops, assessing the normalised remaining energy levels for each known path and monitoring the load on each path. It selects the next possible hop with the highest energy level. It's worth noting that the accuracy of energy consumption data at a node may vary. Thanks to the promiscuous nature of wireless channels, nodes can maintain reasonably precise records by overhearing information from their neighbours. The node's energy consumption can be inferred from its broadcasting activity, which measures its activity or busyness. Load balancing among neighbouring nodes is achieved by selecting the next hop based on energy levels. This approach places a significant focus on determining the load at each node. The term 'multipath' refers to selecting multiple paths between the sender and the destination, each with varying numbers of intermediary nodes. The responsibility of Xij is to calculate the capacity of all nodes involved in different routes across the network. At the same time, Xx represents the processing capability of individual nodes within a single path among multiple paths and the count of nodes within that path. Here, we specifically consider the proposed enhanced multipath routing scenario, which substantially reduces energy consumption while simultaneously maximising energy utilisation.

V. SIMULATION PARAMETERS

Table 1: Simulation Parameter for Deployment of MANET

Parameters	Details
Simulator Tool	NS-2.31
Network Layer Protocol	AODV, AOMDV, ELAM
Terrain Size	1000m*1000m
Network Type	MANET
Number of Mobile Nodes	40,80, 120
Physical Layer	Wireless, 802.11
Simulation Time (Sec)	550Sec
MAC Layer	802.11
Antenna Type	Omni Antenna
Application Layer Data Type	CBR, FTP
Propagation radio Mode	Two ray ground
Energy (Initial)/J	Random

VI. SIMULATION RESULTS

A. Network Architecture for 120 Nodes

In the given scenario or network animation, nodes are equipped with full energy and are capable of sensing their neighbouring nodes to establish connections and transmit data successfully. According to the proposed algorithm, each node senses its neighbours within a radio range of 250m and proceeds to establish connections. Once strong connections are established between source and destination nodes, communication can begin. The initial connection is established from the source to the destination through intermediate nodes. After the robust connection is established, data packets are transmitted through the established route. Once all data packets reach their destination, a new session can be initiated to commence communication.

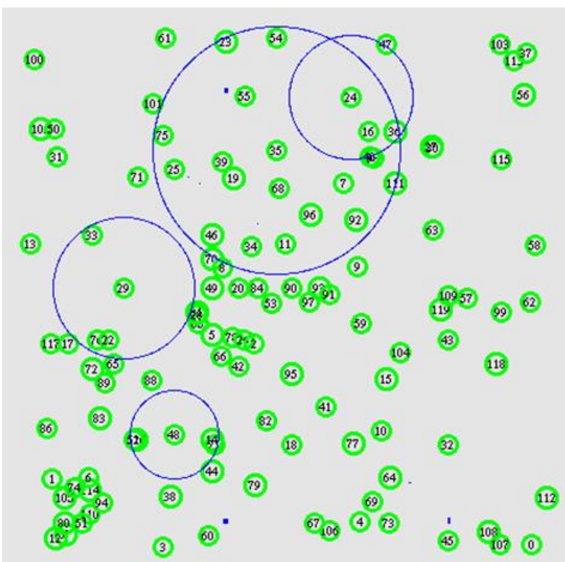

Figure 2: Simulated Architecture with 120 Nodes

B. Packet Delivery Fraction Analysis

The packet delivery ratio (PDR) represents the ratio of received packets to sent packets in the network, providing a crucial performance metric for assessing the network's ability to transmit packets successfully. In the following graph, the performance of the proposed ELAM routing protocol surpasses that of the conventional AODV and AOMDV routing protocols. Under normal multipath routing, the packet delivery fraction is approximately 92%, while in the proposed scheme, the PDR value reaches around 95%. The difference in packet reception and transmission ratios between AODV, AOMDV, and ELAM reveals a substantial disparity in reception rates. A higher number of received packets corresponds to a higher PDR value, indicating superior routing performance. Further performance details are summarised in Table 2.

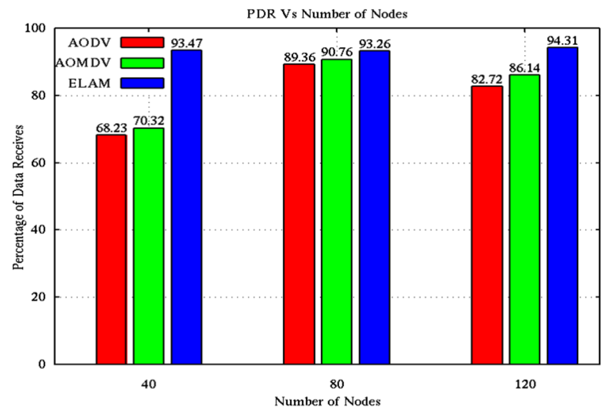

Figure 3: Percentage of Data Received vs. Number of Nodes

Table 2: Percentage of Data Receives

Nodes	AODV	AOMDV	ELAM
40	68.23	70.32	93.47
80	89.36	90.76	93.26
120	82.72	86.14	94.31

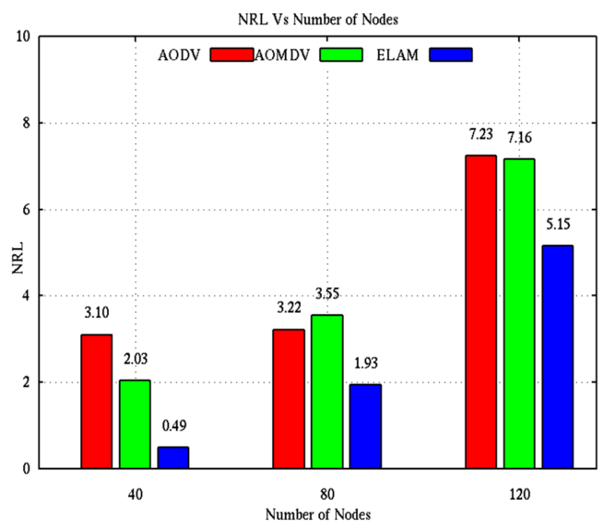

Figure 4: Normal Routing Load vs. Number of Nodes

C. Analysis of Normal Routing Load

The number of routing packets quantifies the routing load, often referred to as 'Hello' packets, delivered in the network to establish connections with receivers. In the graph presented, the routing load of the proposed ELAM scheme is notably lower when compared to both the AODV and AOMDV schemes. This reduction in routing load significantly improves the routing performance of the network. Specifically, AODV exhibits the highest routing overhead compared to AOMDV and ELAM in all node density scenarios. A higher routing load signifies unnecessary flooding within the network, leading to energy wastage. However, the proposed work has incorporated an energy factor to mitigate these issues, ultimately enhancing the routing performance of the multipath protocol by optimising routing procedures and reducing energy consumption.

Table 3: Analysis of Routing Load

Nodes	AODV	AOMDV	ELAM
40	3.1	2.03	0.49
80	3.22	3.55	1.93
120	7.23	7.16	5.15

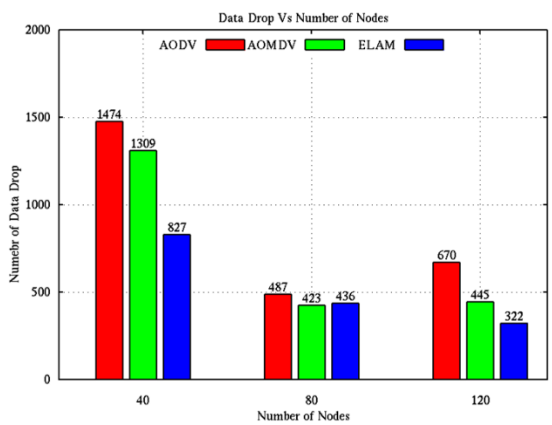

Figure 5: Number of Data Drops vs. Number of Nodes

D. Data Drop Analysis

Data dropping represents a significant factor contributing to network performance degradation or the poor performance of routing protocols. The graph presented here illustrates the data-dropping analysis of the AODV, AOMDV, and ELAM protocols. AODV, due to its high packet dropping rate in a congested network, is not a reliable choice for communication, as successful data delivery is uncertain in such routing scenarios. In this graph, approximately 100 more packets successfully reach their destination in the case of the proposed ELAM scheme compared to the conventional schemes, where significantly fewer packets reach their destination. This demonstrates that the proposed ELAM scheme outperforms AODV and AOMDV protocols regarding routing efficiency within a Mobile Ad Hoc Network (MANET). Detailed performance metrics are presented in Table 4.

Table 4: Analysis of Number of Data Drop

Nodes	AODV	AOMDV	ELAM
40	1474	1309	827
80	487	423	436
120	670	445	322

E. Throughput Analysis

Throughput represents the number of packets sent and received per unit of time. This graph shows that the throughput achieved with normal AODV and AOMDV routing is lower when compared to the proposed ELAM routing in MANET. The ELAM routing technique integrates the node energy module with load balancing and multipath routing, thereby enhancing the performance of the multipath routing protocol.

Figure 6: Throughput in [Mbps] Vs No of Nodes

Table 5: Analysis of Network Throughput [Mbps]

Nodes	AODV	AOMDV	ELAM
40	1.58	1.71	2.96
80	2.04	2.28	3.02
120	2.3	2.68	3.2

In this context, AODV and AOMDV exhibit lower throughput, while the proposed ELAM continuously increases throughput throughout the simulation. The improvement in throughput is consistent across various node density scenarios. While traditional multipath routing provides alternative paths, it often lacks effective load distribution, reducing multipath routing efficiency. The proposed load distribution strategy enhances multipath routing efficiency, especially when considering limited energy resources or a finite network lifetime, as detailed in Table 5.

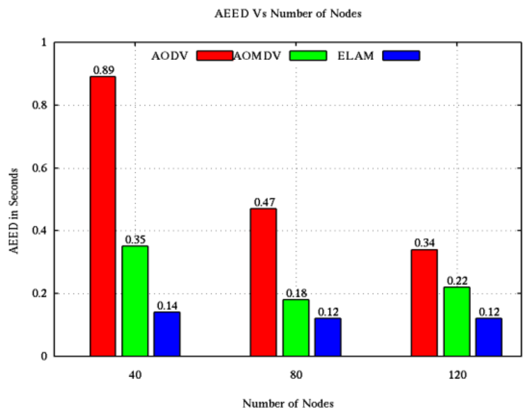

Figure 7: Analysis of AEED vs. No of Nodes

Table 6: Analysis of Average End-to-End Delay [Second]

Nodes	AODV	AOMDV	ELAM
40	0.89	0.35	0.14
80	0.47	0.18	0.12
120	0.34	0.22	0.12

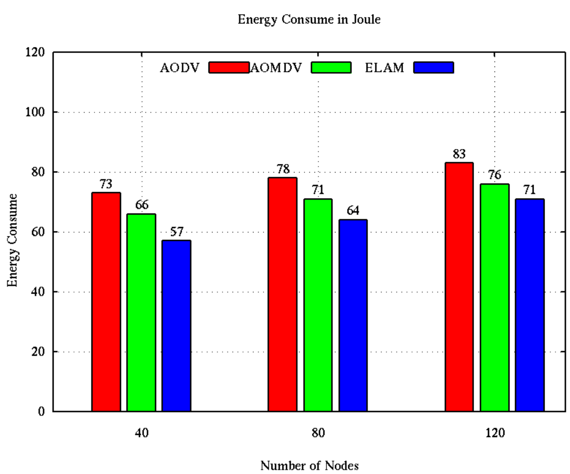

Figure 8: Analysis of Energy Consumption [J] Vs. No of Nodes

F. Average End-to-End Delay

Delays in the network occur due to factors such as insecure links between senders and recipients, and these delays can also consume node resources, particularly when fewer data packets are transmitted. The graph presents the delay analysis of AODV, AOMDV, and MANET's proposed ELAM routing scheme. In the case of AODV, the delay ranges from about 0.89 milliseconds (ms) (maximum) in a 40-node density scenario to 0.34 ms in a 120-node density scenario. Although AOMDV exhibits lower average end-to-end delay (AEED), the ELAM scheme achieves the best performance, owing to its effective load management within the network. ELAM outperforms the other two protocols across node densities, as summarised in Table 6.

Table 7: Analysis of Energy Consumption [Joule]

Nodes	AODV	AOMDV	ELAM
40	73	66	57
80	78	71	64
120	83	76	71

G. Energy Consumption Analysis

Sustaining a connected network topology requires nodes to have sufficient energy while minimising energy consumption during communication. The ELAM scheme aims to discover energy-efficient routes between source and destination nodes. Their straightforward routing strategies increase Energy consumption in AODV and AOMDV. The performance of the entire ad hoc network can be significantly impacted by the failure of a single node, making node energy a critical consideration. The main goal of this research is to prevent network links from deteriorating due to mobile nodes running out of energy. The performance results for the schemes are outlined in Table 7.

CONCLUSION AND FUTURE WORK

Energy is a fundamental requirement for the operation of nodes in Mobile Ad hoc Networks (MANETs). The network's energy availability is critical to communication reliability and efficiency. Wasteful energy consumption within the network can lead to congestion and improper load balancing, significantly affecting routing performance. In this study, we introduced the Energy-Efficient Load Aware Routing (ELAM) routing system, which integrates power-related information into the route discovery process. Our simulation results demonstrated the advantages of adopting the ELAM protocol over traditional AODV and AOMDV protocols. While energy consumption by network nodes remains a pivotal factor influencing performance, optimising the utilisation of available energy resources is equally crucial. By combining multipath routing with effective energy management and load balancing algorithms, we can reduce energy wastage and prevent network congestion, ultimately enhancing the overall performance of the network.

Moreover, with energy considerations, we enhanced an existing on-demand routing protocol, DSR, into the proposed ELAM protocol and evaluated its performance using the NS-2 network simulator. Our simulations revealed that ELAM reduces power consumption related to data packet transmission by one-third compared to AODV and AOMDV. Additionally, it improves the overall performance of the ad hoc network, evidenced by a 10% performance gain in Packet Delivery Ratio (PDR) and a reduction in the number of retransmission attempts, especially with decreasing latency. The achievement of a 10-joule minimum power usage also signifies an improvement in network lifetime. As a future extension of this work, we propose testing the ELAM concept against various ad hoc on-demand multipath routing protocols, such as MP-DSR and TORA. This comparative analysis will help validate the effectiveness and efficiency of the proposed ELAM protocol, paving the way for further advancements in energy-efficient routing strategies for MANETs.

REFERENCES

[1]. Deepak Sharma et al., “Performance Evaluation of MANETs with Variation in Transmission Power using Ad-hoc on-demand Multipath Distance Vector Routing Protocol,” Proceedings of the Fifth International Conference on Communication and Electronics Systems (ICCES 2020).

[2]. M. Tarique, K.E. Tepe, S. Adibi, S. Erfani, “Survey of Multipath Routing Protocols For Mobile Ad Hoc Networks,” Journal of Network and Computer Applications, Vol. 2, No. 6, Pp. 1125–1143, 2009.

[3]. Sudhir K. Routray, Sharmila K. P., “Routing in dynamically changing node location scenarios: A reinforcement learning approach,” Third International Conference on Advances in Electrical, Electronics, Information, Communication and Bio-Informatics (AEEICB), 2017.

[4]. Pramod Kumar, Ashvini Chaturvedi, M. Kulkarni, “Geographical Location Based Hierarchical Routing Strategy for Wireless Sensor Networks,” International Conference on Devices, Circuits and Systems (ICDCS), pp. 9–14, IEEE, March 2012.

[5]. Muath Obaidat, M. A. Ali, M.S. Obaidat and Suhaib Obeidat, “A Novel Multipath Routing Protocol for MANET,” 7th International Conference on Wireless Communications, Networking and Mobile Computing (WiCOM), pp. 1-6, IEEE, September 2011.

[6]. Indu Kashyap & R.K. Rathy, “An Efficient Location-based Reactive Multipath Routing Protocol for MANET,” International Journal of Computer Applications (IJCA), Volume 40, No. 9, pp. 24-29, February 2012.

[7]. Nisha Arora, Ajay Jangra, “GLAAR: Geographic Location-Aware Adaptive Routing in Mobile Ad Hoc Networks (MANETs),” International Journal of Computer Applications, Volume 50, No. 22, July 2012.

[8]. Mahboobeh Abdoos, Karim Faez, Masoud Sabaei, “Position-Based Routing Protocol with More Reliability in Mobile Ad Hoc Network,” World Academy of Science, Engineering and Technology, pp. 304-307, 2009.

[9]. S. J. Sultanuddin, Mohammed Ali Hussain, “STMR – Secure Token-Based Multipath Routing Protocol for Manets Using Hybrid Clustering and Path Selection Algorithm,” International Journal of Innovative Technology and Exploring Engineering (IJITEE), Volume-8, Issue-6, April 2019.

[10]. Sungwook Kim, “Adaptive MANET Multipath Routing Algorithm Based on the Simulated Annealing Approach,” Volume 2014, Article ID 872526, Pp 8, The Scientific World Journal, Hindawi, 2014.

[11]. Waheb A. Jabbar, Wasan Kadhim Saad, and Mahamod Ismail, “MEQSA-OLSRv2: A Multicriteria-based Hybrid Multipath Protocol for Energy-Efficient and QoS-Aware Data Routing in MANET-WSN Convergence Scenarios of IoT,” Vol. 6, Pp. 76546-76572, IEEE Access 2018.

[12]. Swetha M. S, Thungamani M, “A Novel Approach to Secure Mysterious Location-Based Routing For Manet,” International Journal of Innovative Technology and Exploring Engineering (IJITEE), Volume-8 Issue-7 May, 2019.

[13]. Ashish Bagwari, Raman Jee et al., “Performance of AODV Routing Protocol with

increasing the MANET Nodes and its effects on Mobile Ad hoc Networks QoS," 2012 International Conference on Communication Systems and Network Technologies, 2012 IEEE.

[14]. Vishnu Kumar Sharma and Dr. Sarita Singh Bhadauria, "Mobile Agent Based Congestion Control Using Aodv Routing Protocol Technique For Mobile Ad-Hoc Network," International Journal of Wireless & Mobile Networks (IJWMN) Vol. 4, No. 2, April 2012.

[15]. Network Simulator-ns-2 Tutorial Available on the link, [http://www.isi.edu /nsnam/ns /tutorial /index.html]