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A Novel Approach based on Energy Aware Routing for Improving Energy Efficiency in MANETS

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***Abstract*— In modern communication systems, wireless ad hoc networks are essential in which network lifetime and performance depend heavily on the energy economy. However, an energy-efficient protocol is necessary since ad hoc network nodes run on limited battery power and it is impractical to replace or recharge the battery crucial to the ad hoc network's design. In ad hoc networks, the shortest path is always chosen by traditional routing techniques. Ad hoc networks will divide if energy consumption isn't taken into account, as some nodes will quickly run out of power. This work offers a thorough analysis of the energy consumption features of well-known routing methods in wireless ad hoc networks. Also, a new protocol Enhanced Energy Aware Multipath Routing Protocol (EEAMRP) is proposed. EEAMRP takes multipath selection into account to reduce the energy consumption. Number of simulations are carried out over a range of network situations, including different topologies, node configurations, mobility models, and traffic patterns, using Network Simulator 2 (NS2). Enhancing routing protocols to increase the lifetime of ad hoc networks has been a busy field of study in recent years.**

This work's major objective is to assess each protocol's energy efficiency using important performance indicators such as transmission energy, idle energy, receiving energy, node lifetime, and remaining energy. EEAMRP, in particular, performs better than AODV, DSR, and DSDV in terms of transmission energy, idle energy, and receiving energy. By utilizing energy-aware methods and multipath routing, EEAMRP minimises energy consumption through route selection, improving network efficiency and extending node lifetime. Moreover, EEAMRP distributes traffic load efficiently to reduce congestion and energy consumption by dynamically choosing several disjoint pathways between source and destination nodes. This work examines the functionality of three well-known protocols: Dynamic Source Routing (DSR), Ad hoc On-Demand Distance Vector (AODV), and Destination-Sequenced Distance Vector (DSDV), in comparison to the novel Enhanced Energy-Aware Multipath Routing Protocol (EEAMRP). Through meticulous analysis, EEAMRP emerges as a standout performer, showcasing superior energy efficiency. Its adeptness in maximizing the lifespan of ad-hoc networks signifies a promising advancement in the realm of wireless communication protocols.

***Index Terms*— AODV, DSDV, DSR, EEAMRP, Routing Protocols, NS-2**

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I. INTRODUCTION

Wireless ad hoc networks, which provide flexible connectivity without requiring a fixed infrastructure, have become a significant communication paradigm for dynamic and resource-constrained contexts [1]. These networks allow nodes to instantly build temporary networks by communicating with one another directly or through intermediary nodes [1, 2]. Ad hoc networks are useful in a variety of situations where conventional infrastructure-based networks are unfeasible or unavailable, such as disaster recovery, military operations, sensor networks, and vehicle communication. In ad hoc networks, routing protocols are essential because they make it easier for nodes to create effective communication channels. However, protocol design is severely hampered by the special qualities of ad hoc networks, such as their dynamic topology, constrained bandwidth, and node mobility [3]. Since most nodes are powered by batteries with a limited capacity, energy economy is a critical factor to take into account while designing an ad hoc routing protocol [2].

Researchers have developed a number of routing protocols that are designed to maximise energy consumption while preserving efficient communication in order to address these issues. Because of their unique methods to route discovery and maintenance, three of these protocols—Ad hoc On-Demand Distance Vector (AODV), Dynamic Source Routing (DSR), and Destination-Sequenced Distance Vector (DSDV)—have attracted a lot of interest. To create and maintain routes in ad hoc networks, these protocols use reactive, proactive, or hybrid tactics, each with pros and downsides for scalability, energy consumption, and routing overhead [4].

Apart from these widely accepted protocols, new methods keep coming out to improve network speed and energy economy in ad hoc settings. To further optimise energy utilisation and extend network lifetime, one such method is the Enhanced Energy-Aware Multipath Routing Protocol (EEAMRP), which introduces cutting-edge approaches like multipath routing and energy-aware mechanisms. This work intends to investigate and contrast these well-known routing methods' energy consumption characteristics in wireless ad hoc networks. Taking advantage of large-scale simulations using Network Simulator 2 (NS2), we examine how well AODV, DSR, DSDV, and EEAMRP function in various network settings. In order to determine the energy efficiency and efficacy of each protocol, this work focuses on analysing critical performance indicators including transmission energy, idle energy, receiving energy, remaining energy, and terminated nodes. This paper attempts to provide important insights into the design and optimisation of energy-efficient routing strategies for wireless ad hoc networks by offering a thorough analysis of these routing protocols. Future protocols and network architectures aiming at enhancing the sustainability and dependability of wireless communication systems in ad hoc contexts may be influenced by the findings.

II. PROBLEM STATEMENT AND MOTIVATION

In adhoc networks, energy efficiency is a key concern. Thus, it is essential to comprehend the behaviour of mobile adhoc routing protocols in terms of transmission energy, idle energy, receiving energy, residual energy, and terminated nodes in order to create routing strategies that are energy-efficient and to improve the ad hoc networks' sustainability and reliability. As a result, the goal of this research is to thoroughly analyse the protocols in order to pinpoint their advantages and disadvantages as well as offer guidance for future attempts to create energy-aware routing protocols.

This research suggests a unique routing strategy for ad hoc networks with a focus on energy efficiency. and compares the energy consumption features of popular routing protocols used in wireless ad hoc networks with the proposed approach. Eminent routing protocols considered in this work along with the proposed approach are described briefly in this section:

Ad hoc On-Demand Distance Vector (AODV)

AODV is a reactive routing technology that establishes routes only when necessary. To create routes between nodes, it makes use of on-demand route discovery and distance vector routing concepts [5]. In order to guarantee loop-free paths, AODV keeps routing tables up to date with sequence numbers [6]. It also facilitates route maintenance by sending out route error notifications and updates on a regular basis. It is appropriate for dynamic networks due to its ease of route discovery and recovery, even though large-scale installations will result in an increase in control overhead [5].

Dynamic Source Routing (DSR)

Another reactive routing algorithm for wireless ad hoc networks that depends on source routing is called dynamic source routing (DSR). Each data packet in DSR contains all of the route information needed to reach the destination, enabling intermediate nodes to forward packets according to the pre-planned path [7, 8]. Although

DSR removes the requirement for keeping routing tables at intermediate nodes, route caching and route-finding cost may result in increased overhead. It is appropriate for highly dynamic situations due to its adaptability to changing network conditions, yet networks with high mobility and frequent topology changes may cause its performance to deteriorate [2].

Destination Sequence Distance Vector (DSDV)

DSDV is a proactive routing strategy for wireless ad hoc networks based on the traditional distance vector algorithm. In order to track the freshness of routes, it keeps a routing table at each node with entries for all reachable destinations and sequence numbers. To distribute routing information and keep loop-free pathways, neighbouring nodes exchange periodic route updates [3]. DSDV offers reduced latency and faster convergence for route formation; however, because it requires frequent updates, its overhead rises with network size and mobility, making it less appropriate for highly dynamic applications [9].

Enhanced Energy Aware Multipath Routing Protocol (EEAMRP)

A unique routing system called EEAMRP has been proposed to maximise energy efficiency in wireless ad hoc networks. It combines energy-conscious methods with multipath routing approaches to increase network efficiency and extend node lifetime. EEAMRP prioritises routes with enough residual energy to guarantee balanced energy depletion, distributes traffic load to reduce congestion, and dynamically chooses numerous disjoint paths between source and destination nodes. It is a viable solution for enhancing network performance and sustainability in energy-constrained areas because of its capacity to adjust to changing network circumstances and effectively use existing energy resources [10].

III. Proposed Scheme

A number of crucial procedures and changes to the current codebase are necessary for the simulation environment's implementation of the Enhanced Energy-Aware Multipath Routing Protocol (EEAMRP). EEAMRP uses multipath routing and energy-aware techniques to maximise energy consumption and extend node lifetime in wireless ad hoc networks. Here are the specific steps to implement the proposed scheme:
Algorithm Design: Based on energy concerns, EEAMRP dynamically chooses a number of discontinuous pathways between the source and destination nodes. Routes with enough remaining energy are given priority by nodes to guarantee even energy depletion throughout the network. The routing protocol incorporates energy-aware methods to oversee and regulate energy usage, modifying routing choices according to node energy levels and network circumstances.
Protocol Design: To facilitate efficient communication and coordination between network nodes, EEAMRP specifies message formats, protocols, and state maintenance techniques. Route discovery, maintenance, and error handling procedures are made easier by the specification of message types such route request (RREQ), route reply (RREP), route error (RERR), and acknowledgment (ACK). Protocol design considerations guarantee the development of a loop-free path and efficient use of energy.
Implementation Approach: The protocol logic and behaviour of EEAMRP are defined using the Tcl (Tool Command Language) scripting language in the Network Simulator 2 (NS2) environment. To include EEAMRP functionality into NS2, special modules and event-driven simulation scripts are created, allowing wireless ad hoc network simulation with EEAMRP routing capabilities. The current NS2 codebase is modified to provide event handlers, protocol state machines, and packet formats unique to EEAMRP.
Modification in .cc and .h files: The EEAMRP-defined routing logic and message processing methods are implemented through modifications made to the .cc (source code) files. This covers route finding, maintenance, and forwarding based on energy-conscious standards. The declaration of data structures, constants, and function prototypes required for EEAMRP implementation is done by editing the .h (header) files. This guarantees appropriate incorporation and communication with additional NS2 components.
Recompiling NS2: Next step is to recompile NS2 to modify the environment and experimental setup to fit the needs of the proposed scheme. When NS2 is recompiled to integrate the newly suggested EEAMRP algorithm, it enhances the NS2 simulation capabilities by incorporating a novel algorithm intended to enhance network performance and energy efficiency.
Connectivity with NS2: EEAMRP's smooth integration with the NS2 simulation environment guarantees interoperability with other NS2 elements including traffic generators, energy models, and mobility models. To ensure that EEAMRP and other simulation components interface and function properly, compatibility testing is carried out.

Fig. 1 shows the step-by-step process for the development and implementation of the proposed scheme.

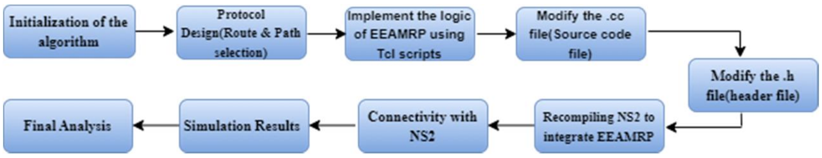

Figure 1. Process for development and Implementation of EEAMRP

IV. Performance Metrics

This section insights the various performance parameters used for the analysis and evaluation of proposed scheme and its comparison with the performance of existing routing protocols. Total number of nodes in the network are designated by N.

Transmission energy (Et): It is the energy consumed by a network node in forwarding packets across the network[8]. The total network energy utilized in transmitting different packets by the network nodes is calculated by taking the sum of transmission energy of individual nodes. Average transmission energy is defined by (1).

$$Average\ \mathrm{Et} = \frac{\sum \mathrm{Et}}{N} \tag{1}$$

Receiving energy (Er): It is the energy consumed by a network node in receiving different packets from other nodes[11]. The total network energy consumption in receiving the packets is computed by taking the sum of energy consumed by individual nodes in receiving the packets from other nodes in the network. Average energy used in receiving is defined by (2).

$$Average\ \mathrm{Er} = \frac{\sum \mathrm{Er}}{N} \tag{2}$$

Idle energy (Ei): The network nodes do not always transmit or receive; sometimes they just do nothing but still consume some energy[12]. The total idle energy is the sum of the energy consumed by all the individual network nodes in idle state. Average idle energy consumed is defined by (3).

$$Average\ \mathrm{Ei} = \frac{\sum \mathrm{Ei}}{N} \tag{3}$$

Remaining energy (Er): This is the energy left with the network nodes at the end of the simulation time. The total remaining energy is the sum of the remaining energies of all the individual network nodes. Larger remaining energy indicates longer the network lifetime. Average remaining energy is given by (4).

$$Average\ \mathrm{Er} = \frac{\sum \mathrm{Er}}{N} \tag{4}$$

Average Total Energy consumption (Ec): Total energy consumption is taken as the sum of total transmission energy, total energy consumption in receiving packets and total idle energy consumed by the nodes in the network[13][14]. Average energy consumption is given by (5).

$$Average\ \mathrm{Ec} = \frac{\sum \mathrm{Ec}}{N} \tag{5}$$

Network lifetime (Tl): Network lifetime is the duration when all the nodes in the network are active i.e. the energy level of all the nodes are above the minimum threshold value required to be active. If simulation starts at time t0 and let us assume that first node in the network terminates at time t1 then the difference (t1-t0) is considered as the network lifetime.

Terminated nodes (Tn): Those nodes in the network, whose energy level is reduced below a threshold level are termed as terminated nodes. These nodes either have limited capability or they are just not capable of performing any function in the network [8, 15]. In this research work, nodes with energy less than 100 Joules have been considered as terminated or dead nodes and it is assumed that these nodes are not capable of performing any network function.

V. Simulation Setup And Result Analysis

Network Simulator 2 (NS2), a popular discrete event simulator for network research, is utilised to run the simulations. NS2 offers a versatile and adaptable framework for simulating and evaluating a range of network scenarios and protocols. The Random Waypoint mobility model is used to create mobility patterns that simulated node movement after nodes were randomly placed around the simulation region. The simulation scenario encompasses an area of 1000 by 600 meters with a simulation time of 1000 seconds. Each node within the network is initialized with an initial energy of 1200 joules. The pause time between consecutive simulations is set at 10 seconds, maintaining a constant interval. The number of nodes deployed within the network varies, allowing for diverse network configurations and scalability assessments. This scenario design ensures a comprehensive evaluation of energy consumption, network performance, and scalability under varying node densities and deployment scenarios. Various parameter values used during simulations performed are given in Table I.

TABLE I: PARAMETER VALUES USED IN SIMULATION

Simulation Parameter	Value
Simulator	NS-2.35
Routing Protocols	AODV, DSDV, DSR, EEAMRP
Packet Size	512 Bytes
Node Count	10, 30, 50, 70, 90
Simulation Area	1000m x 600m
Mobility Model	Random Waypoint model
Antenna	Omni directional
No. of Connections	70%
Traffic Type	CBR
Simulation Time	1000 seconds
Initial Node Energy	1200 joules
Pause Time	10 seconds
Max. Speed	20 m/s
Packet Rate	8 packets/second

Average Energy Consumption in Transmission

The average energy consumed during forwarding the packets from one node to other as a result of simulation on NS-2 simulator is shown in Table II. Fig. 2 shows the average energy consumption in transmission for the four protocols (AODV, DSDV, DSR and EEAMRP) as a function of total node count.

TABLE II: AVERAGE ENERGY CONSUMPTION IN TRANSMISSION

Node Count	Energy Consumption (Joule)			
	AODV	DSDV	DSR	EEAMRP
10	243.24	198.36	228.84	172.5
30	271.38	177.84	284.7	144.54
50	207.9	215.88	220.44	159.84
70	165.18	144.54	186.36	147.36
90	172.32	177.6	199.8	131.4

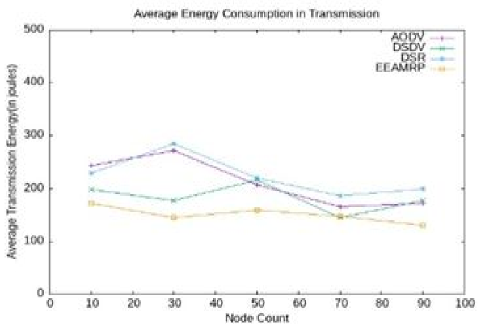

Figure 2. Average Energy Consumption in Transmission

It is evident that when node density rises from 10 to 30 nodes, energy usage rises noticeably in AODV and DSR protocols. It makes sense because, in a location with low node density, all of the nodes are dispersed widely apart and, for the most part, are not in communication range of one another. As a result, there is an increase in packet transmission and energy usage. Further increases in node density cause the network load to be distributed among more nodes, which lowers each node's average energy consumption. When comparing EEAMRP to AODV, DSDV, and DSR, we find that EEAMRP has the lowest average energy consumption during transmission. EEAMRP continuously exhibits decreased average energy consumption rates through rigorous simulations and careful analysis, indicating its effectiveness in optimising energy utilisation within the network.

Average Total Energy Consumption in Receiving

The average total energy consumed during transmission of packets, receiving of the packets by the node as a result of simulation on NS-2 simulator is shown in Table III. Fig. 3 shows the average energy consumption in receiving for the four protocols (AODV, DSDV, DSR and EEAMRP) as a function of total node count.

TABLE III: AVERAGE ENERGY CONSUMPTION IN RECEIVING

Node Count	Energy Consumption (Joule)			
	AODV	DSDV	DSR	EEAMRP
10	315.48	303.65	324.16	298.74
30	592.43	494.07	614.76	450.07
50	655.34	483.68	665.57	472.11
70	653.26	502.50	651.78	460.57
90	685.68	495.53	656.07	473.75

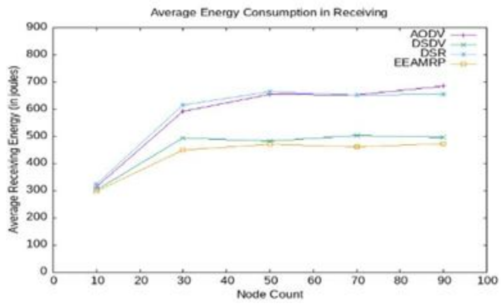

Figure 3. Average Energy Consumption in Receiving

EEAMRP uses less energy on average during receiving than AODV, DSDV, and DSR. The energy-aware methods, multipath routing, and adaptive algorithms of EEAMRP are the reasons for its supremacy. Through efficient energy use and waste reduction, EEAMRP is very good at lowering total energy costs. It uses less energy because of its multipath capabilities, which reduce congestion and packet retransmissions. In dynamic ad hoc situations, EEAMRP's efficiency is improved through dynamic adaptation to shifting network conditions. These characteristics position EEAMRP as a top option for increasing energy efficiency and extending network life.

Average Energy Consumption in Idle Mode

The node is neither sending or receiving packets when it is in idle mode. Since the node must constantly listen to the wireless medium to find a packet it should receive in order to transit it further or switch into receive mode, this mode uses substantial power. The average energy consumed during the idle mode as a result of simulation on NS-2 simulator is shown in Table IV. Fig. 4 shows the average energy consumption in idle mode for the four protocols (AODV, DSDV, DSR and EEAMRP) as a function of total node count.

TABLE IV: AVERAGE ENERGY CONSUMPTION IN IDLE MODE

Node Count	Energy Consumption (Joule)			
	AODV	DSDV	DSR	EEAMRP
10	307.31	378.54	334.99	297.80
30	128.18	279.35	160.77	120.80
50	192.08	195.82	227.19	163.88
70	222.24	250.22	260.60	190.31
90	203.85	172.90	214.50	168.96

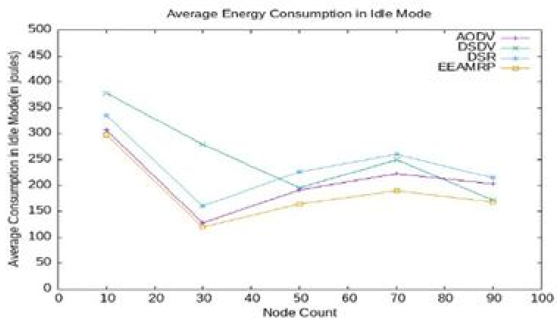

Figure 4. Average Energy Consumption in Idle Mode

It is intriguing to observe that DSDV after EEAMRP, known for its cost-effectiveness in transmit and receive modes, paradoxically emerges as the most energy-intensive protocol during idle mode. This anomaly can be attributed to DSDV's proactive nature, necessitating continuous table management operations alongside wireless medium monitoring. However, it is noteworthy that despite this, DSDV remains comparatively less expensive than AODV and DSR in both transmit and receive modes. Moreover, it is particularly significant to highlight that EEAMRP stands out as the most efficient protocol across all modes, including idle mode, showcasing its superiority in energy conservation and network optimization.

D. Average Total Energy Consumption

Total energy consumption reflects the overall energy consumption pattern of various routing protocols as per the defined parameters. Table V reflects the simulation results which are plotted in Fig. 5.

TABLE V: AVERAGE TOTAL ENERGY CONSUMPTION

Node Count	Energy Consumption (Joule)			
	AODV	DSDV	DSR	EEAMRP
10	866.03	880.55	887.99	769.04
30	991.99	951.26	1060.23	715.41
50	1055.32	895.38	1113.20	795.83
70	1040.68	897.26	1098.74	798.24
90	1061.85	846.03	1070.37	774.11

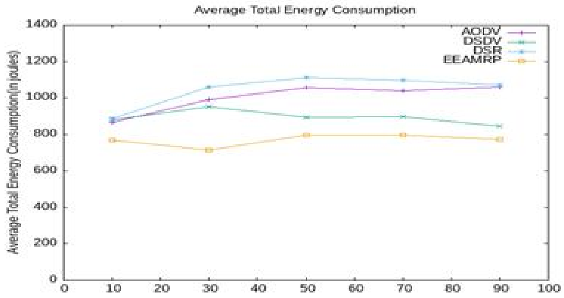

Figure 5.
Average Total Energy Consumption

Simulation results shows that EEAMRP is the least expensive protocol. And the performance of AODV and DSR is almost similar, with AODV being slightly better than DSR.

Average Remaining Energy

The protocol's overall performance is directly reflected by the average remaining energy; the more is the energy conserved, the longer is the network lifetime. The average total energy consumed during simulation is shown in Table VI. Fig. 6 shows the graph for average total energy consumption in idle mode for the four protocols (AODV, DSDV, DSR and EEAMRP) as a function of total node count.

TABLE VI: AVERAGE REMAINING ENERGY

Node Count	Energy Consumption (Joule)			
	AODV	DSDV	DSR	EEAMR
10	333.96	319.44	312.01	430.95
30	208.00	248.73	139.76	484.58
50	144.67	304.61	86.79	404.16
70	159.31	302.73	101.25	401.75
90	138.14	353.96	129.62	425.88

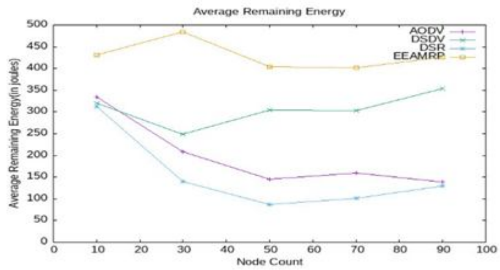

Figure 6. Average Remaining Energy

The simulation findings demonstrate that the average residual energy for AODV, DSDV and DSR varies slightly at low node densities, but as the density grows residual energy in AODV and DSR gets much less as compared to DSDV and EEAMRP. EEAMRP outperforms the other three protocols throughout all the node densities, reflecting the probability of longer network lifetime.

Network Lifetime

Network lifetime represents the duration when all nodes of network are operational. The results generated are given in Table VII. Fig. 7 shows the graphical view of the network lifetime for the protocols under analysis.

TABLE VII: NETWORK LIFETIME

Node Count	Network Lifetime (seconds)			
	AODV	DSDV	DSR	EEAMRP
10	782.99	776.99	760.99	840.01
30	757.99	746.87	722.99	858.99
50	716.99	768.99	716.99	814.44
70	731.99	758.99	729.99	812.04
90	728.99	768.99	735.99	834.10

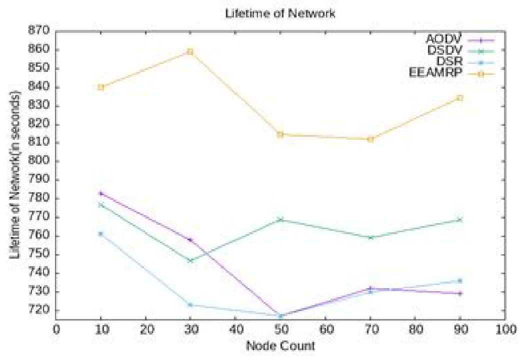

Figure 7. Network Lifetime

According to simulation results, EEAMRP performs the best in terms of network longevity. At any node density, every node is operational at the same time for the maximum amount of time.

Terminated Nodes

Table VIII shows the terminated nodes after simulation is over. Fig. 8 represents the graph for terminated nodes.

TABLE VIII: NUMBER OF TERMINATED NODES

Node Count	Number of nodes			
	AODV	**DSDV**	**DSR**	**EEAMRP**
10	1	2	2	1
30	4	5	7	1
50	10	9	18	4
70	8	9	25	8
90	21	19	22	12

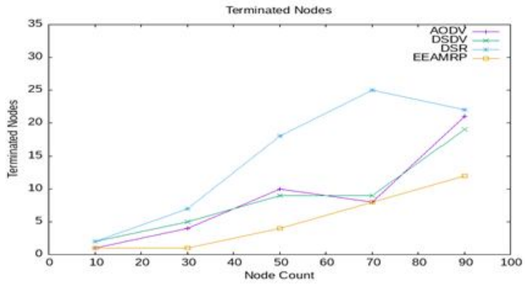

Figure 8. Number of Terminated Nodes

Simulation results demonstrates that at low node density all the four protocols show very few terminated nodes. At higher node densities, EEAMRP demonstrates superior performance in terms of minimizing the number of terminated nodes compared to AODV, DSDV, and DSR. Through comprehensive simulations, EEAMRP consistently exhibits the ability to effectively manage network resources, optimize routing paths, and mitigate energy depletion, resulting in a lower number of nodes being terminated prematurely. This phenomenon underscores EEAMRP's efficacy in prolonging network longevity and sustaining connectivity, making it a preferred choice for energy-efficient routing in wireless ad hoc networks.

VI. CONCLUSION AND FUTURE SCOPE

In conclusion, there is enormous potential for wireless ad hoc network advancement with the Enhanced Energy-Aware Multipath Routing Protocol (EEAMRP). In comparison to established protocols like AODV, DSDV, and DSR, EEAMRP has demonstrated greater energy efficiency and robustness through in-depth research and simulations. Its cutting-edge features, like multipath routing techniques and energy-aware processes, provide observable advantages in terms of extending network lifespan and maximising resource usage. Incorporating cutting-edge technology like machine learning could improve EEAMRP's capabilities even more. As it continues to develop, EEAMRP has the potential to completely transform wireless communication by offering improved performance and seamless connectivity in a variety of contexts.

This novel protocol has bright future potential, with opportunities to improve scalability and robustness. There is a lot of promise in trying to maximise energy efficiency and take advantage of new technologies. Validation in the real world will confirm effectiveness and direct improvement initiatives. Adoption of the protocol is expected to revolutionise wireless communication across multiple domains as it develops.

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