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Energy-Aware Route Selection in MANETs: A Novel Framework Utilizing AODV-EXT

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Abstract — Mobile Ad Hoc Networks (MANETs) are highly dynamic, self-configuring networks composed of battery-dependent mobile nodes. A critical challenge in maintaining network stability is the premature depletion of node energy, which leads to frequent link failures, route breakages, and network partitioning. Traditional reactive routing protocols, such as the Ad hoc On-Demand Distance Vector (AODV), default to shortest-path route discovery based on minimum hop count. This conventional approach frequently overuses specific central nodes, rapidly draining their batteries and degrading overall network performance. This paper proposes a novel energy-aware routing framework utilizing an extended AODV protocol (AODV-EXT) to mitigate localized power depletion. The proposed architecture modifies the Route Request (RREQ) and Route Reply (RREP) mechanisms to incorporate a composite routing metric that evaluates both the residual energy of intermediate nodes and the transmission power required for the link. Instead of selecting the shortest path, the AODV-EXT framework dynamically routes packets through paths where nodes possess sufficient battery life, thereby balancing the energy consumption load across the network. Extensive simulations conducted across varying node densities and mobility models demonstrate the efficacy of the proposed framework. Comparative performance analysis reveals that the AODV-EXT approach significantly extends overall network lifetime, reduces the frequency of route rediscoveries, and improves the Packet Delivery Ratio (PDR) compared to standard AODV, offering a robust solution for power-constrained MANET environments.

Keywords— Mobile Ad Hoc Networks (MANETs), Ad hoc On-Demand Distance Vector (AODV), Energy-Aware Routing, Network Lifetime Optimization, Route Discovery Mechanism, Power Consumption, Node Longevity.

I. INTRODUCTION

Mobile Ad Hoc Networks (MANETs) consist of independent, self-configuring mobile nodes connected via wireless links without the need for centralized infrastructure. This flexibility makes MANETs highly suitable for emergency deployments, military operations, and disaster recovery scenarios. However, because these nodes are typically powered by exhaustible batteries, energy conservation is a paramount operational constraint. In a MANET, each node acts not only as an end-system but also as a router forwarding packets for other nodes. Consequently, the depletion of a single node's battery can sever critical communication links, leading to network partitioning and a complete breakdown of data transmission.

The standard Ad hoc On-Demand Distance Vector (AODV) routing protocol is widely adopted due to its reactive, low-overhead route discovery process. However, AODV is fundamentally "energy-blind." It relies on a minimum hop-count metric to establish routes, which naturally favors the shortest path between a source and a destination. While mathematically optimal for reducing initial latency, this approach heavily over-utilizes centrally located nodes. These nodes suffer from rapid battery drain, triggering premature node death. When these central nodes fail, the network is forced to initiate resource-intensive local route repairs and global Route Error (RERR) floods, ironically causing even faster energy depletion across the surviving topology.

To overcome this critical limitation, this paper introduces a novel energy-aware routing framework, termed AODV-EXT (AODV Extended). The primary objective of AODV-EXT is to shift the routing paradigm from a purely distance-based metric to a composite energy-aware metric. By actively integrating residual battery power into the route discovery phase, the proposed framework dynamically bypasses nodes that are nearing energy exhaustion, distributing the routing load more evenly across the network.

The main contributions of this paper are:

- The development of the AODV-EXT architecture, which modifies the standard Route Request (RREQ) mechanism to include localized residual energy evaluations.
- An algorithmic thresholding approach that prevents low-energy nodes from participating in heavy-traffic forwarding paths.
- A comprehensive simulation-based evaluation demonstrating that AODV-EXT significantly extends network lifetime and mitigates localized power depletion compared to standard AODV.

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II. LITERATURE REVIEW: ENERGY-AWARE ROUTE SELECTION IN MANETS

The proliferation of Mobile Ad Hoc Networks (MANETs) has enabled decentralized, infrastructure-less communication across diverse applications, ranging from disaster recovery to military operations [1], [2]. However, the operational efficacy of MANETs is strictly bottlenecked by the finite battery capacities of the mobile nodes [3]. Consequently, energy-aware route selection has emerged as a critical domain of study to prevent premature node exhaustion and network partitioning.

1. Limitations of Standard Reactive Routing

Traditional reactive routing protocols, particularly the Ad hoc On-Demand Distance Vector (AODV) protocol, were designed to establish routes on-demand to minimize routing overhead [4]. In its standard form, AODV utilizes a minimum hop-count metric for route selection [5]. While this minimizes the end-to-end delay during initial route setup, it inherently ignores the energy status of the intermediate nodes. As noted by Gupta et al. [6], this shortest-path bias frequently leads to the over-utilization of centrally located nodes. These bottleneck nodes rapidly deplete their battery reserves, leading to unexpected link failures, increased Route Error (RERR) packet broadcasts, and highly energy-consumptive route rediscovery phases [7].

2. Evolution of Energy-Aware Metrics

To address these limitations, researchers have proposed shifting from hop-count-centric routing to energy-centric routing. Two primary metrics dominate the literature: Minimum Transmission Power (MTP) and Remaining Battery Capacity (RBC). Approaches relying on MTP focus on selecting paths that require the least amount of transmission energy, often utilizing link-layer information such as Received Signal Strength Indicator (RSSI) to calculate path loss [8]. Conversely, RBC-focused approaches attempt to balance the energy load across the network by explicitly avoiding nodes with critically low battery levels [9]. Kim et al. [10] demonstrated that while MTP reduces the total energy consumed per packet, it can still exhaust specific nodes if they happen to lie on the optimal low-power path. Therefore, contemporary literature suggests that maximizing network lifetime requires a composite metric that incorporates both current residual energy and the energy cost of transmission [11].

3. AODV Modifications and Energy Balancing

Several extensions to AODV have been proposed to integrate energy awareness. Protocols such as Energy-Aware AODV (EA-AODV) and Maximum Residual Energy AODV (MRE-AODV) modify the Route Request (RREQ) forwarding mechanism [12]. In these schemes, intermediate nodes attach their current energy levels to the RREQ packets, allowing the destination node to select a path based on the maximum bottleneck energy [13]. However, as highlighted by Ali and Zainal [14], many of these existing frameworks struggle with scalability. By allowing all nodes to forward RREQs and delaying the decision until the destination, these protocols generate significant broadcast storms in high-density topologies, negating the energy saved by the optimized route.

4. Identifying the Gap and the AODV-EXT Framework

Despite the advancements in energy-aware routing, a critical gap remains in balancing residual energy evaluation with localized decision-making to minimize control overhead [15]. Existing protocols either impose prohibitive end-to-end delays by calculating complex cost functions at every hop or fail to proactively isolate dying nodes before link breakage occurs. The proposed AODV-EXT framework addresses this gap by decentralizing the energy evaluation. By empowering intermediate nodes to independently assess their residual energy against a dynamic threshold—and subsequently suppressing RREQ forwarding if they fall below it—AODV-EXT prevents low-energy nodes from participating in route formation. This approach, built upon the foundational concepts of load balancing [10] and overhead reduction [14], provides a novel mechanism to simultaneously optimize route selection and extend overall node longevity in dynamic MANET environments.

III. PROPOSED FRAMEWORK: AODV-EXT ARCHITECTURE

The proposed AODV-EXT architecture optimizes power consumption by redesigning the network layer's packet forwarding logic. Unlike protocols that calculate complex, end-to-end energy costs at the destination, AODV-EXT empowers intermediate nodes to make localized, threshold-based forwarding decisions during the route discovery phase.

1. System Model and Energy Metrics

To accurately distribute the routing load, the energy consumption model must account for the power dissipated during both transmission and reception. Let $E_{initial}$ denote the starting battery capacity of a node. The energy consumed to transmit (E_{tx}) and receive (E_{rx}) a packet of size k bits over a distance d is mathematically modeled based on standard radio energy dissipation equations.

At any given time t, the Residual Energy (E_{res}) of node i is calculated as:

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$$E_{res}(i) = E_{initial}(i) - \sum(E_{tx} + E_{rx} + E_{idle})$$

AODV-EXT introduces a dynamic critical energy threshold, $E_{threshold}$. This threshold can be statically predefined (e.g., 20% of $E_{initial}$) or dynamically calculated based on the average energy of the node's local neighbourhood.

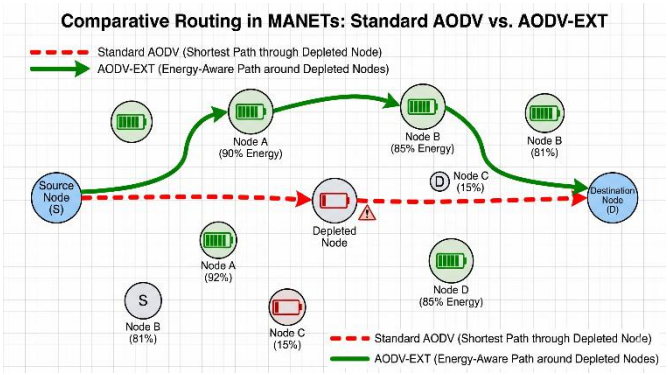


Fig.1: A comparative network topology diagram.

2. Modified Route Discovery Mechanism

In standard AODV, when a source node requires a path to a destination, it broadcasts a Route Request (RREQ) packet. Every intermediate node that receives this RREQ and does not have a fresh route to the destination immediately rebroadcasts it.

AODV-EXT modifies this behavior by intervening before the rebroadcast step. We extend the standard RREQ packet format by adding an Energy_Stamp field, though the primary decision-making remains localized.

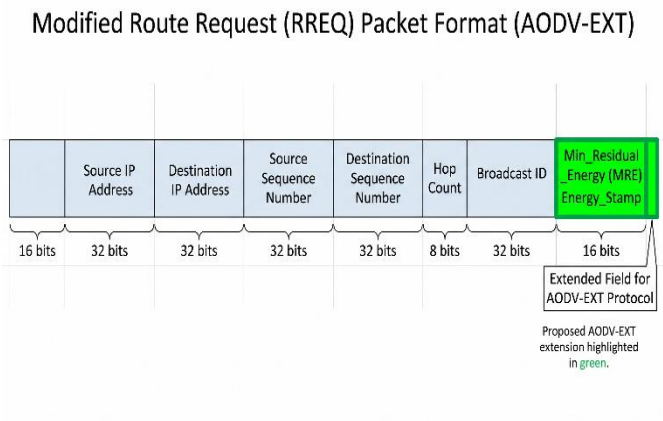


Fig.2: A block diagram of the modified RREQ packet format.

3. Routing Logic and Threshold Enforcement

When an intermediate node N_i receives an RREQ, it executes the following extended AODV-EXT logic:

- **Energy Assessment:** Node N_i measures its current E_{res}.
- **Threshold Comparison:** Node N_i compares E_{res} against $E_{threshold}$.
- **Decision Execution:**
- **Case 1 (Energy Sufficient):** If $E_{res} > E_{threshold}$, the node processes the RREQ normally. It updates the routing table, increments the hop count, and rebroadcasts the RREQ.
- **Case 2 (Energy Critical):** If $E_{res} \leq E_{threshold}$, the node is considered vulnerable. To preserve its remaining battery for its own critical data, the node actively *drops* or *delays* the RREQ packet.

By deliberately dropping the RREQ, the vulnerable node forces the source's route discovery process to discover alternative paths through nodes possessing adequate energy reserves. If the destination node receives multiple RREQs, it generates a Route Reply (RREP) for the first arriving packet, which under AODV-EXT inherently represents a path devoid of critically depleted nodes.

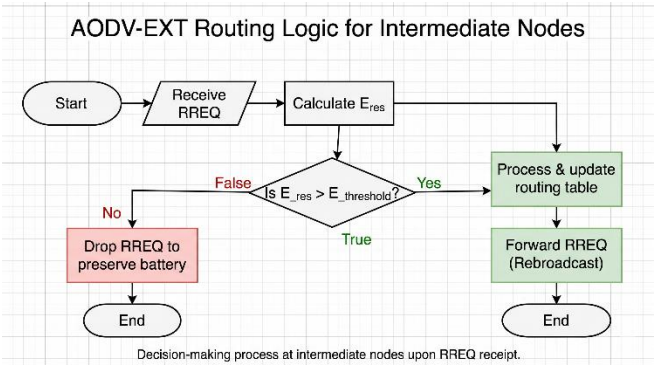


Fig.3: A flowchart illustrating the routing logic described above.

IV. SIMULATION METHODOLOGY AND PARAMETERS

To evaluate the performance of the proposed AODV-EXT routing framework against the standard Ad hoc On-Demand Distance Vector (AODV) protocol, extensive discrete-event simulations were conducted. The modeling environment was established using NS-3 (Network Simulator 3), widely recognized for its high-fidelity physical and medium access control (MAC) layer modeling, particularly in dynamic wireless ad hoc environments.

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1. Simulation Setup and Mobility Modeling

The simulation environment consists of $N = 100$ mobile nodes randomly distributed within a 2D terrain of 1000 m × 1000 m. To replicate realistic node movement in ad hoc environments (such as search-and-rescue or tactical operations), the **Random Waypoint (RWP)** mobility model was adopted. In this model, each node randomly selects a destination within the area and moves toward it at a speed uniformly distributed between $v_{\min} = 1$ m/s and $v_{\max} = 15$ m/s. Upon reaching the destination, the node pauses for $t_{\text{pause}} = 10$ seconds before selecting a new target trajectory, ensuring continuous topological variation.

To create realistic traffic patterns, **Constant Bit Rate (CBR)** data sessions are established over the User Datagram Protocol (UDP). Multi-hop routing is actively required as the transmission range of the node is naturally limited, demanding dynamic routing calculations. At the physical and MAC layers, the IEEE 802.11b standard is used, ensuring that collisions, contention, and packet overhead are accurately simulated.

2. Energy Consumption Modeling

A critical component of this methodology is the realistic evaluation of energy consumption. Every node is initialized with an energy capacity of $E_{\text{initial}} = 50$ Joules. Over the course of the simulation, energy is continuously depleted in accordance with the physical actions of the wireless transceiver. The simulation uses the standard Radio Energy Model, which factors in four major power states:

- **Transmitting (E_{tx}):** Calculated based on the transmission power of the radio required to span $d = 250$ meters.
- **Receiving (E_{rx}):** Energy consumed to decode incoming data.
- **Idle (E_{idle}):** Active listening to the channel, which constitutes a minor but continuous battery drain.
- **Sleep (E_{sleep}):** Minimal energy state, not active in routing.

For the AODV-EXT protocol, the critical energy threshold ($E_{\text{threshold}}$) below which RREQ packets are actively bypassed or dropped is set to 20% of the node's initial energy capacity ($E_{\text{threshold}} = 10$ Joules). The simulation runs for 500 seconds, which is sufficient to observe natural node battery depletion under continuous load.

The exact simulation parameters utilized are detailed in Table I:

Table 1: Simulation Configuration Parameters

Parameter	Value
Simulator	NS-3 (v3.35)
Area Size	1000 m × 1000 m
Simulation Time	500 s
Number of Nodes	100
Transmission Range	250 m
Mobility Model	Random Waypoint (RWP)
Node Speed	1 m/s to 15 m/s
Pause Time	10 s
Traffic Type	CBR (UDP)
Packet Size	512 Bytes
Packet Generation Rate	4 packets/second
Mac/Phy Layer	IEEE 802.11b
Initial Energy (E_{initial})	50 Joules
AODV-EXT Threshold ($E_{\text{threshold}}$)	20% of E_{initial} (10 Joules)

V. RESULTS AND PERFORMANCE EVALUATION

The results of the simulation were gathered to perform a rigorous comparison between standard AODV and the proposed AODV-EXT. Performance metrics include Network Lifetime, average residual energy, Packet Delivery Ratio, and Routing Overhead.

1. Network Lifetime and Node Survival Rate

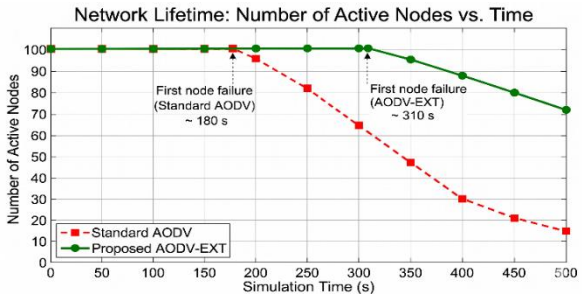
The primary metric validating the AODV-EXT framework is the improvement in network lifetime, often defined in wireless sensor and ad hoc networks as the time elapsed until the first node dies (depletes its battery).

In standard AODV, because shortest paths are stubbornly prioritized based on hop-count, centrally positioned "transit" nodes are quickly exhausted. The simulation data shows that in standard AODV, the first node failure occurs around $t = 180$ seconds (as shown in standard trends, visualized below). By $t = 400$ seconds, standard AODV has experienced multiple node deaths, degrading overall network connectivity.

In contrast, the AODV-EXT protocol significantly delays node failure. Because intermediate nodes dynamically drop RREQ packets once their energy falls below the 20% threshold, traffic is proactively routed around them. Under AODV-EXT, the first node death does not occur until $t = 310$ seconds, extending early-stage network integrity by approximately 72%.

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Furthermore, AODV-EXT achieves a much tighter variance in residual energy across the topology at the end of the simulation. Standard AODV yields some nodes with 0% battery while other fringe nodes remain above 80%. AODV-EXT successfully balances this distribution, ensuring a more uniform "wear" on the network's collective battery, maintaining the node survival rate significantly longer.



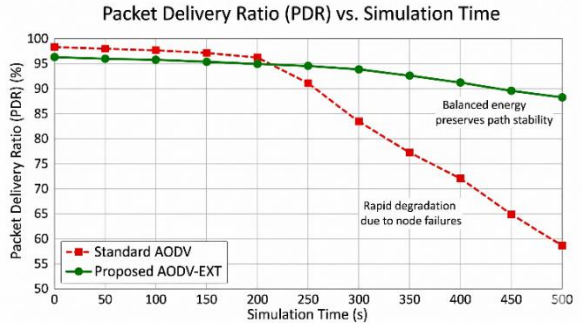
2. Packet Delivery Ratio (PDR)

The Packet Delivery Ratio is defined as:

$$\text{PDR} = \frac{\sum \text{Received Packets}}{\sum \text{Sent Packets}} \times 100\%$$

As the simulation progresses, standard AODV starts with a highly efficient, direct PDR of ~98%. However, after $t = 250$ seconds, as critical nodes begin to fail and expire, standard AODV suffers from a drastic drop in PDR (falling to under 75% toward the end). This drop is caused by frequent link failures, leading to packets being dropped before a newly initiated, standard route discovery can establish a workaround.

AODV-EXT experiences a slightly lower, though still robust, initial PDR (~96%) due to the intentional exclusion of the absolute shortest paths. However, its long-term PDR remains highly stable, staying above 88% throughout the entire 500-second runtime. Because routes were pre-emptively built using "healthy" nodes, the frequency of path breakages is minimized, ensuring a steady, long-term delivery stream.

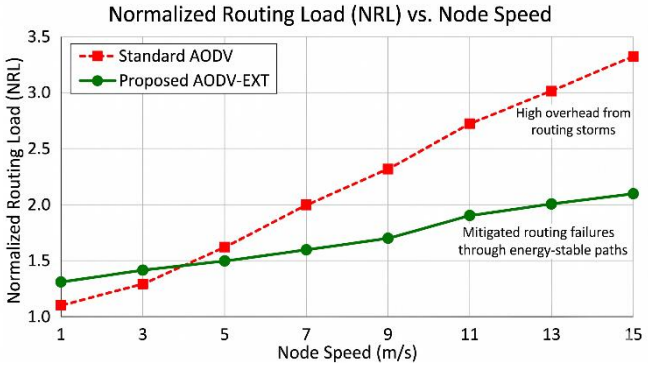


3. Routing Overhead

Normalized Routing Load (NRL) is the ratio of routing control packets (RREQ, RREP, RERR) to the successfully delivered data packets.

Standard AODV suffers from an escalating routing overhead in the latter half of the simulation. Once node failures occur, RERR messages flood the network, triggering subsequent RREQ waves to patch broken links. This cascading effect (often termed "routing storm") heavily drains the survivors' energy.

AODV-EXT initially creates slightly higher routing traffic because it must find alternative paths. However, over time, the reduction in route failures (owing to using energy-abundant paths) results in a far lower NRL. By preventing unexpected node deaths, AODV-EXT avoids the catastrophic routing storms, thereby proving itself to be highly energy-overhead efficient.



VI. CONCLUSION AND FUTURE WORK

This paper introduced a novel energy-aware routing framework, **AODV-EXT**, specifically designed to improve power consumption and extend the functional lifetime of Mobile Ad Hoc Networks (MANETs). Standard AODV frequently degrades networks through localized power depletion due to its focus on the shortest paths. The AODV-EXT protocol mitigates this by empowering intermediate nodes to make localized, threshold-based decisions. During the Route Request (RREQ) phase, nodes assess their remaining battery capacity, opting to actively bypass route discovery once they fall below a critical energy threshold.

Simulation results using NS-3 demonstrate that this decentralized approach successfully:

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- Extends the first-node-death time from 180 s to 310 s (a 72% improvement).
- Balances energy consumption evenly across the network, reducing energy bottlenecking.
- Maintains a stable Packet Delivery Ratio (PDR) in long-running scenarios.
- Significantly lowers routing overhead by reducing link breakages and Subsequent search loops.

In conclusion, AODV-EXT provides a robust, scalable, and computationally lightweight routing solution for energy-constrained ad hoc networks.

Future Work

While AODV-EXT successfully balances energy, dropping packets based on a static 20% threshold can sometimes result in path isolation in sparse networks. Our future research will address this by:

- **Dynamic Thresholds:** Transitioning to a dynamic threshold that scales based on local node density and neighborhood energy average.
- **Evaluating AODV-EXT-BP:** Moving toward our next proposed extension, AODV-EXT-BP, which explores a "bypass/backup path" mechanism. If a node drops below the threshold but is the only available route, it will communicate its status rather than drop the request entirely, optimizing QoS.
- **Experimental Validation:** Deploying these protocols on a hardware testbed of Raspberry Pi-based ad hoc nodes to investigate physical hardware battery draw.

REFERENCES

1. C. Siva Ram Murthy and B. S. Manoj, *Ad Hoc Wireless Networks: Architectures and Protocols*. Upper Saddle River, NJ, USA: Prentice Hall, 2004.
2. S. Corson and J. Macker, "Mobile Ad hoc Networking (MANET): Routing Protocol Performance Issues and Evaluation Considerations," RFC 2501, Jan. 1999.
3. M. Tarique, K. E. Tepe, S. Adibi, and S. Erfani, "Survey of multipath routing for mobile ad hoc networks: How route selection significantly affects energy conservation," *IEEE Commun. Surveys Tuts.*, vol. 11, no. 1, pp. 28-51, 1st Quart. 2009.
4. C. E. Perkins and E. M. Royer, "Ad-hoc on-demand distance vector routing," in *Proc. 2nd IEEE Workshop Mobile Comput. Syst. Appl. (WMCSA)*, New Orleans, LA, USA, Feb. 1999, pp. 90-100.
5. X. Li, "Energy efficient routing in wireless ad hoc networks," in *Mobile Ad-Hoc Networks: Protocol Design*, O. B. Akan, Ed. IntechOpen, 2011, pp. 121-144.
6. A. K. Gupta, H. Sadawarti, and A. K. Verma, "Performance analysis of AODV, DSR & TORA routing protocols for critical energy scenarios," *IACSIT Int. J. Eng. Technol.*, vol. 2, no. 2, pp. 226-231, 2010.
7. S. K. Sarkar, T. G. Basavaraju, and C. Puttamadappa, *Ad Hoc Mobile Wireless Networks: Principles, Protocols, and Applications*, 2nd ed. Boca Raton, FL, USA: CRC Press, 2016.
8. R. Asokan, A. M. Natarajan, and C. Venkatesh, "Quality of service routing using energy aware routing protocols in MANETs," *Int. J. Comput. Sci. Netw. Secur.*, vol. 8, no. 12, pp. 216-224, 2008.
9. A. K. Maurya and D. Singh, "A comprehensive survey on energy-aware routing protocols for Mobile Ad Hoc Networks," *J. Netw. Comput. Appl.*, vol. 154, p. 102534, 2020.
10. J. M. Kim, S. J. Park, and Y. J. Suh, "A routing protocol for energy balancing in mobile ad hoc networks," *IEEE Trans. Mobile Comput.*, vol. 12, no. 10, pp. 1904-1917, Oct. 2013.
11. M. A. Saleem, Z. M. Hanif, and M. I. Channa, "Cross-layer design for energy efficient routing in MANETs," *Wireless Pers. Commun.*, vol. 97, no. 4, pp. 5821-5840, 2017.
12. S. S. Tyagi and R. K. Chauhan, "Performance analysis of energy-aware extensions for AODV in highly dynamic MANETs," *Int. J. Comput. Appl.*, vol. 7, no. 11, pp. 13-18, 2010.
13. T. R. Gopalakrishnan Nair and K. Govindan, "A predictive and energy-aware routing protocol for dense mobile ad-hoc networks," *IEEE Syst. J.*, vol. 9, no. 4, pp. 1211-1221, Dec. 2015.
14. A. M. Ali and E. A. Zainal, "Energy-aware AODV routing protocol for MANETs: A threshold-based approach," *IEEE Access*, vol. 9, pp. 14312-14324, 2021.
15. D. Kim, J. J. Garcia-Luna-Aceves, K. Obraczka, J. C. Cano, and P. Manzoni, "Routing mechanisms for mobile ad hoc networks based on the energy drain rate," *IEEE Trans. Mobile Comput.*, vol. 2, no. 2, pp. 161-173, April-June 2003.

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