Indian Journal of Data Communication and Networking (IJDCN)
ISSN: 2582-760X (Online), Volume-4 Issue-4, June 2024

A Comprehensive Survey of Load Balancing Techniques in Multipath Energy-Consuming Routing Protocols for Wireless Ad hoc Networks in MANET

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Abstract: ***As technology progresses, networking undergoes continuous evolution to align with contemporary trends. Mobile Ad hoc Networks (MANETs) have emerged as a pivotal technology facilitating communication among mobile nodes sans a central administering node. MANETs find diverse applications spanning communication networks to battlefield scenarios. Nonetheless, MANETs encounter various challenges, including load balancing, energy efficiency, packet loss, and connection failures. Routing, among these challenges, assumes a pivotal role in defining network performance and connectivity capacity within MANETs. Moreover, the energy consumption of mobile nodes, often reliant on batteries with limited rechargeability, presents a significant concern in MANETs. This paper delves into diverse techniques devised to tackle the issues of energy efficiency and load balancing in MANETs. Additionally, it offers a comparative analysis to consolidate the survey findings. The outcomes of this study enrich our comprehension of energy-efficient and load-balanced routing protocols in MANETs, thereby facilitating the design and deployment of efficient networking solutions.***

Keywords: Energy Efficiency, Load Balancing, Battery Constraint, Mobile Nodes, MANET

I. INTRODUCTION

Mobile Ad hoc Networks (MANETs) [1] comprise independent mobile nodes (MNs) that rely on each other for wireless communication, operating without a fixed infrastructure. In this network, each MN sends and receives data to and from other nodes, acting as a terminal node when transmitting data, while intermediate nodes function as routers, forwarding data. MANET architecture, depicted in Figure 1, lacks central control due to the dynamic nature of nodes freely joining and leaving the network. A significant challenge in MANETs is the limited battery life of MNs, which cannot be replaced, necessitating optimization of energy usage and power management. As devices like cell phones and PDAs typically have limited battery capacity, energy-efficient protocols have been developed to minimize overall energy consumption, extending network lifetime[2].

Manuscript received on 10 April 2024 | Revised Manuscript received on 29 May 2024 | Manuscript Accepted on 15 June 2024 | Manuscript published on 30 June 2024.
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These protocols can be classified into Minimum Energy routing protocols, focusing on efficient source-to-destination routes considering energy consumption, and Maximum Network Lifetime routing protocols, aiming to balance remaining battery energy during route selection to ensure prolonged network efficiency [3].

Mobile nodes consume energy in various modes including transmitting, receiving, idle/sleep, and remaining energy. This paper explores energy efficiency and load balancing in MANETs, examining techniques and protocols designed to optimize energy consumption and workload distribution among nodes [4]. Additionally, we provide a comparative analysis to summarize survey findings and identify areas for further research and development. Understanding the energy-efficient and load-balancing aspects of MANETs facilitates the design of more efficient and sustainable wireless networks [5].

A. Advantages of MANET:

- Rapid network establishment facilitated by wireless connectivity, ensuring quick deployment.
- Flexible network expansion from any location, providing adaptability to changing environments.
- Enhanced reliability achieved through multiple path routing, minimizing single points of failure.
- Dynamic network configuration enables seamless integration of new nodes and departure of existing nodes without disrupting connectivity.

B. Applications of MANET[6]:

MANET boasts a diverse array of applications spanning various domains. Some notable application scenarios include:

- Sensor Network: Utilized in home automation, health monitoring systems, weather monitoring stations, wildlife tracking, and more.
- Entertainment: Deployed in organizational setups, campus environments, virtual classrooms, and wireless communication setups during meetings.
- Emergency Services: Critical in search and rescue missions, disaster management operations, law enforcement activities, firefighting efforts, and facilitating hospital operations.

- Tactical Networks: Vital for military operations, weapon management on the battlefield, and ensuring effective communication in tactical environments.
- Coverage Extension: Utilized to extend the coverage and scalability of cellular networks, and establishing connections between the human body and the physical world through the Internet of Things (IoT).

Table 1: MANET Application Scenarios and Examples

Application Scenario	Examples
Sensor Network	Home applications, Health Monitoring, Weather Monitoring, Biological Animal Movement, etc.
Entertainment	Organizations and campus settings, Virtual classrooms, Wireless communications during meetings.
Emergency Services	Search and rescue operations, Disaster Management, Policing and firefighting, In support of hospital management.
Tactical Networks	Military applications, Management of Weapons in battlefield.
Coverage Extension	Scalability procedure of cellular network access, Linking the human body with the real world by use of Internet of Things.

The paper is organized into several sections, each addressing essential facets of energy efficiency and load balancing in MANETs. Section II delves into routing protocols, while Section III concentrates on energy-efficient routing protocols. In Section IV, the discussion centers on load balancing, and Section V offers a survey of existing techniques in energy efficiency and load balancing. This structured approach facilitates a thorough comprehension of the subject matter and sheds light on research gaps and challenges concerning the attainment of efficient energy utilization and load balancing in MANETs.

II. ROUTING PROTOCOLS

Routing protocols play a pivotal role in determining the most efficient path for data transmission across various networks such as MANETs, the Internet, and VANETs [7]. In MANETs, routing poses unique challenges due to the dynamic nature of mobile nodes (MNs) and the frequent alterations in network topology caused by their mobility. As a result, routing protocols must adapt dynamically to ensure energy efficiency, load balancing, and seamless connectivity for effective communication among MNs. These protocols can be broadly classified into three categories based on their operational approaches: table-driven routing protocols, on-demand routing protocols, and hybrid routing protocols [8].

A. Table-driven routing protocols, also referred to as proactive routing protocols, continually update their routing tables in response to any changes in the network topology. These protocols maintain routing tables containing information about every node in the network, which is utilized for routing purposes. The routing tables are regularly updated by neighboring nodes, ensuring the accuracy and currency of routing information. Examples of table-driven routing protocols include DSDV, WRP, and STAR.

B. On-demand routing protocols, alternatively known as reactive routing protocols, dynamically establish routes based on the system's demands. These protocols involve two primary phases: route discovery and route maintenance. During the route discovery phase, route-request packets (RREQ) are initiated from the source node and disseminated through intermediate nodes. Upon reaching the destination, a route-reply packet (RREP) is transmitted back to the source node via the intermediate nodes. Examples of on-demand routing protocols comprise DSR and AODV.

C. Hybrid routing protocols amalgamate features of both proactive and reactive protocols to capitalize on their respective strengths. These protocols endeavor to minimize traffic overhead through proactive mechanisms while reducing route discovery latency via reactive mechanisms. Examples of hybrid routing protocols include ZRP and BGP.

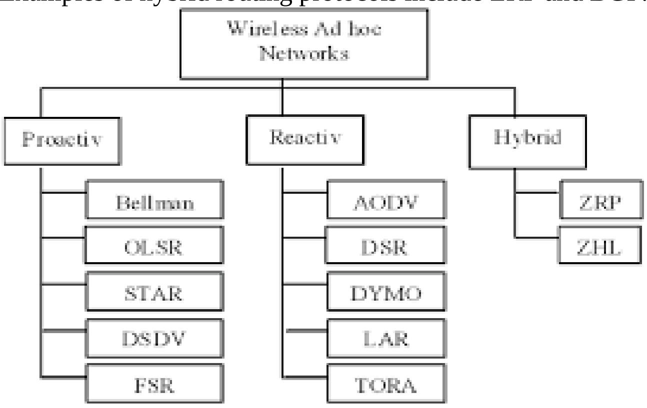

Fig.1 Classification of Routing Protocols

Figure 1 depicts the categorization of diverse routing protocols. Selecting the most suitable routing protocol for a MANET scenario is crucial, considering its unique requirements and characteristics.

In essence, routing protocols within MANETs are instrumental in establishing optimal routes for data transmission. Table-driven protocols maintain routing tables with regular updates, while on-demand protocols dynamically create routes as per system needs. Hybrid protocols amalgamate advantages from proactive and reactive methods. The decision on routing protocol selection hinges on factors like energy efficiency, load distribution, and the necessity for minimizing route discovery latency.

III. ENERGY EFFICIENT ROUTING PROTOCOLS

Energy-efficient routing protocols aim to extend the lifespan of the network by establishing optimal routes between pairs of nodes [9]. This objective is achieved by minimizing both active and idle communication modes for mobile nodes (MNs). Various strategies are employed to optimize energy consumption in both types of communication.

1. Transmission Control Approach: This strategy focuses on two main parameters: transmission power and communication energy. Minimum Energy Broadcasting adjusts the radio power of each node during active communication to the destination node. By utilizing multi-hop transmission from the source node to other nodes, the network can minimize energy consumption. Flooding is a commonly used technique for broadcasting messages within the network.

Retrieval Number:100.1/ijdcn.D503504040624
DOI:10.54105/ijdcn.D5035.04040624
Journal Website: https://www.ijdcn.latticescipub.com

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Lattice Science Publication (LSP)

2. Load Distribution Approach: This approach seeks to optimize active power usage by ensuring a balanced distribution of energy among different nodes. By selecting suitable routing paths, this approach maximizes network lifetime by evenly distributing energy consumption across the network.
3. Battery-Cost Lifetime-Aware Routing: This approach operates in two ways. Firstly, it reduces the number of nodes required for routing, thus lowering energy expenditure and optimizing network resources. Secondly, it considers the remaining battery power at different nodes and assigns routes with a hierarchy of low residual power, ensuring efficient energy utilization and extending network lifespan [8].

By implementing these energy-efficient routing techniques, MANETs can effectively manage energy resources and prolong overall network lifespan. These approaches address the critical challenge of energy consumption in MANETs and contribute to enhancing the efficiency and sustainability of wireless communication.

IV. LOAD BALANCING

Efficient load balancing is essential for optimizing network resource utilization and mitigating traffic congestion in MANETs [10][24][25][26][27][28]. It entails effectively distributing traffic among multiple routes based on network traffic assessments. Load balancing holds particular significance for time-sensitive applications necessitating high performance and optimal resource allocation.

Over time, various methodologies have been introduced to tackle load balancing challenges in MANETs. Several of these methods integrate on-demand routing with route discovery mechanisms. Figure 2 delineates the classification of load balancing protocols, which can be segmented as follows[11]:

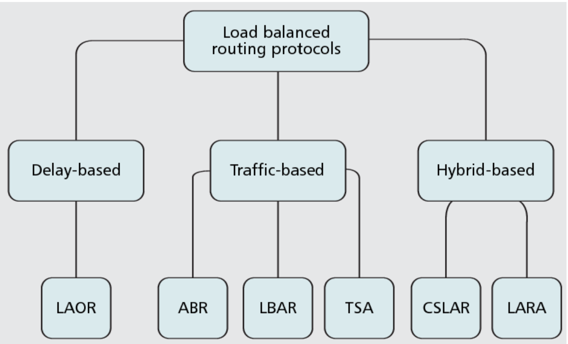

Fig. 2 Classification of Load Balancing Protocols

a. Delay-Based Approach: Load balancing is accomplished in this approach by steering traffic away from nodes with high delay. By doing so, overall network performance can be enhanced. LAOR is a commonly used protocol in this category.

b. Traffic-Based Approach: Load balancing is achieved by evenly dispersing traffic load across the network in this approach. The objective is to prevent certain nodes from becoming overloaded while others are underutilized. Protocols such as ABR, LBAR, and TSA fall under this category.

c. Hybrid-Based Approach: This approach combines both traffic and delay-based techniques to achieve load balancing. By taking into account both traffic load and delay metrics, the goal is to optimize traffic distribution and improve overall network performance. CSLAR and LARA are common examples of protocols in this category.

These load balancing techniques enhance MANET efficiency by efficiently managing network traffic and ensuring equitable utilization of network resources. By distributing traffic load across multiple routes, congestion can be minimized, leading to a significant improvement in overall network performance.

V. LITERATURE SURVEY

The paper [10] explores Mobile Ad hoc Networks (MANETs), which are collections of mobile nodes interconnected for communication without a central administering node. MANETs find applications in various domains, but face challenges like load balancing, energy efficiency, and packet loss. Routing is crucial in defining network performance and connectivity in MANETs. Energy consumption is a significant concern due to battery-dependent mobile nodes. The paper discusses techniques to address energy efficiency and load balancing challenges in MANETs, offering a comparative analysis for summarizing the survey findings.

The paper [12] addresses energy efficiency and data loss in Mobile Ad hoc Networks (MANETs) by proposing an optimized Genetic Algorithm (GA) combined with Forwarding Factor (FF) techniques and integrating it with the Ad-hoc On Demand Multi Path Distance Vector routing protocol (AOMDV). This approach aims to optimize route selection based on distance, network congestion, and energy utilization. Performance evaluation against existing protocols demonstrates its efficacy in mitigating data loss and improving energy efficiency in MANETs.

The paper [11] introduces the Multipath Classification Algorithm (MCA) to identify load balancing in Internet routes, extending traceroute with optimizations to reduce probing costs. Through extensive measurements, it finds that load balancing is prevalent and strategies are mature in both IPv4 and IPv6 networks.

The paper [13] emphasizes the necessity of developing effective load balancing solutions for Internet of Things (IoT) networks, particularly Low-Power Lossy Networks (LLNs). While highlighting the IPv6 Routing Protocol for Low-Power and Lossy networks (RPL) as a standard protocol for IoT networks, it underscores the absence of load balancing provisions in RPL. Load balancing is crucial for ensuring fair distribution of traffic load among nodes in LLNs, impacting network connectivity, stability, reliability, and lifetime. The paper reviews existing load balancing routing protocols and underscores the importance of designing efficient and reliable load balancing solutions tailored for IoT networks.

The paper [14] proposes the Efficient Load Balancing AOMDV (ELAOMDV) Scheme to address congestion in Mobile Adhoc Networks (MANETs).

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ELAOMDV integrates delay estimation rate control to evenly distribute workload across available routes, reducing congestion and optimizing bandwidth usage. Performance evaluations show ELAOMDV outperforms previous methods, demonstrating its effectiveness in improving network performance in MANETs.

The paper [15] presents LBAS, a novel load-balanced adaptive clustering scheme for wireless sensor networks (WSNs). LBAS efficiently allocates resources and extends network lifespan through hierarchical clustering and dynamic load balancing. Simulations show LBAS outperforms existing algorithms, underscoring its potential to enhance WSN efficiency and longevity.

The paper [16] explores load balancing self-optimization (LBSO) in 5G networks, addressing challenges and proposing solutions. Through simulation and optimization algorithms, it evaluates LBSO's impact on handover probability, radio link failure, and spectral efficiency. Results favor Distance-based Optimization for improving network performance, underscoring the role of user location in optimizing handover control parameters for future mobile networks.

The paper [17] introduces the Traffic and Energy Aware Load Balancing (TEALB) Routing Protocol for Mobile Ad hoc Networks (MANETs) to enhance packet delivery ratio and transmission reliability. Divided into AOMDV Routing, TEALB Routing, and route maintenance segments, TEALB enables effective multipath transmission and adjustments based on node mobility. Using NS2 for simulation, performance metrics like packet delivery ratio, end-to-end delay, routing overhead, and throughput are evaluated. Comparative analysis with SMLB-MANETs and MCLB-MANETs shows TEALB-MANETs outperforming in packet delivery ratio, throughput, and reducing end-to-end delay and routing overhead.

The paper [18] presents ACOLBR, a novel MANET routing protocol utilizing Ant Colony Optimization (ACO) to address real-time data transmission challenges and load imbalance due to congestion. It employs red and blue ant colonies to balance load across multiple paths based on network conditions, outperforming existing protocols in load balancing efficiency.

The paper [19] introduces MMEE, an adaptive Multipath Multichannel Energy Efficient (N-channel) routing approach for MANETs. MMEE selects routes based on predictive energy consumption per packet, available bandwidth, queue length, and channel utilization. It balances network load with multipath routing and reduces collisions through multichannel assignment. MMEE outperforms existing protocols in terms of data received, throughput, and energy utilization, as demonstrated in comparative analysis with other multichannel medium access techniques.

The paper [20] explores the challenges of gateway load balancing in Integrated Internet-MANET networks, where the gateway acts as a bridge between MANET and the wired Internet. It highlights the importance of load balancing to improve network performance by distributing the load among different gateways. The paper provides a comprehensive survey of existing load balancing solutions and proposes a framework for comparing gateway load balancing strategies.

The paper [21] discusses the challenges faced by Mobile Adhoc Networks (MANETs) concerning energy constraints and security. It emphasizes the necessity for efficient routing protocols to minimize packet loss and energy consumption while extending network lifetime. Proposing a multipath load balancing approach using the Namib Updated Shepherd Optimisation Algorithm (NUSOA), the study aims to optimize gateway node selection and path choices based on various factors like path cost, link cost, residual energy, and distance. This hybrid optimization strategy addresses congestion detection and node availability constraints to enhance load balancing in MANETs.

The paper [22] introduces an efficient delay-based load balancing routing protocol for Mobile Ad hoc Networks (MANETs) using Ad hoc On-demand Multipath Distance Vector (AOMDV) routing. It highlights the benefits of multipath routing for load distribution in dynamic MANET topologies. The protocol incorporates a data_packet_counter variable in each node's routing table to calculate the load on different paths. New packets are forwarded through less loaded paths, reducing end-to-end delay and packet loss ratio. The proposed system simplifies complexity, enhances packet delivery ratio, throughput, and routing load normalization even with increased scalability.

The paper [23] presents a load-balanced multi-path routing protocol with energy constraints (EE-LB-AOMDV) for Mobile Ad Hoc Networks (MANETs) amidst the growing scope of Internet of Things and Internet of Vehicles. It categorizes multiple paths based on hop-count, round-trip time, and residual energy, optimizing data transmission quality. Simulation results demonstrate significant improvements in packet delivery ratio (PDR), average end-to-end delay, routing overhead, energy consumption, and route rediscovery frequencies.

TABLE II: Comparative Analysis of All Lecture Reviews

Paper	Main Focus	Key Contributions
[3]	MANETs Challenges and Solutions	Comparative analysis of energy efficiency and load balancing techniques in MANETs; highlights routing's critical role and energy consumption challenges.
[4]	Energy Efficiency and Data Loss in MANETs	Proposes an optimized GA with FF technique integrated into AOMDV routing; improves energy efficiency and reduces data loss in MANETs.
[5]	Internet Route Load Balancing	Introduces the MCA for identifying load balancing in Internet routes; presents optimizations for cost-effective probing and analyzes load balancing in IPv4 and IPv6 networks.
[6]	Load Balancing in IoT Networks	Reviews load balancing challenges in IoT networks; underscores the need for efficient load balancing solutions tailored for IoT networks.

[7]	Congestion Mitigation in MANETs	Proposes ELAOMDV for congestion mitigation in MANETs; integrates delay estimation rate control for optimal workload distribution and bandwidth utilization.
[8]	Load Balancing in Wireless Sensor Networks	Presents LBAS for load-balanced adaptive clustering in WSNs; extends network lifespan through hierarchical clustering and dynamic load balancing.
[9]	Load Balancing Self-Optimization in 5G Networks	Investigates LBSO's impact on handover probability, radio link failure, and spectral efficiency in 5G networks; favors Distance-based Optimization for improved network performance.
[10]	Traffic and Energy-Aware Load Balancing in MANETs	Introduces TEALB Routing Protocol for MANETs; enhances packet delivery ratio and transmission reliability through effective multipath transmission and adjustments.
[11]	Real-Time Data Transmission and Load Balancing	Proposes ACOLBR for real-time data transmission and load balancing in MANETs; utilizes ACO to balance load across multiple paths and improves load balancing efficiency.
[12]	Multipath Multichannel Energy-Efficient Routing	Introduces MMEE for adaptive multipath multichannel routing in MANETs; optimizes data transmission quality and reduces collisions through multichannel assignment.
[13]	Gateway Load Balancing in Integrated Internet-MANET	Reviews gateway load balancing challenges and solutions in Integrated Internet-MANET networks; proposes a framework for comparing gateway load balancing strategies.
[14]	Multipath Load Balancing in MANETs	Proposes NUSOA for multipath load balancing in MANETs; optimizes gateway node selection and path choices to enhance load balancing considering various factors.
[15]	Delay-Based Load Balancing in MANETs	Introduces a delay-based load balancing routing protocol using AOMDV in MANETs; enhances packet delivery ratio, throughput, and routing load normalization.
[16]	Load-Balanced Multi-Path Routing with Energy Constraints	Presents EE-LB-AOMDV for load-balanced multi-path routing in MANETs; optimizes data transmission quality based on hop-count, round-trip time, and residual energy, yielding significant performance improvements.

VI. RESULT

The comparative analysis of the literature reviews on various aspects of Mobile Ad Hoc Networks (MANETs) and related technologies provides valuable insights into the current research landscape. Here are some key conclusions drawn from the analysis:

1. Diverse Challenges Addressed: The surveyed papers address a wide range of challenges in MANETs, including energy efficiency, load balancing, congestion mitigation, routing optimization, and gateway load balancing.
2. Innovative Solutions Proposed: Each paper proposes innovative solutions to tackle specific challenges. These solutions range from optimized routing algorithms, adaptive clustering schemes, and load-balanced multipath routing protocols to gateway load balancing strategies and congestion control mechanisms.
3. Performance Improvement: Across the board, the proposed solutions demonstrate significant performance improvements compared to existing methods. These improvements are observed in various metrics such as packet delivery ratio, end-to-end delay, routing overhead, energy consumption, and throughput.
4. Optimization Techniques: Many papers leverage optimization techniques such as Genetic Algorithms (GA), Ant Colony Optimization (ACO), and adaptive algorithms to enhance network performance and efficiency.
5. Simulation and Evaluation: Simulation results play a crucial role in evaluating the proposed solutions. Most papers utilize simulation tools like NS2 and OMNET++ to assess the performance of their algorithms under different scenarios and network conditions.
6. Comparative Analysis: Comparative analyses highlight the strengths and weaknesses of existing approaches and provide valuable insights for future research directions. These analyses aid in identifying the most effective techniques for addressing specific challenges in MANETs.

In summary, the surveyed literature demonstrates the ongoing efforts to overcome the inherent challenges of MANETs and improve their performance, reliability, and efficiency. The proposed solutions offer promising avenues for further exploration and development in the field of mobile ad hoc networking.

VII. CONCLUSION

Energy efficiency and load balancing are major challenges in mobile ad hoc networks (MANETs), prompting extensive research efforts to develop effective algorithms. This paper offers a concise overview of existing approaches addressing energy efficiency and load balancing. Nevertheless, further progress is needed, including the development of new protocols integrating innovative metrics. These protocols should strive to improve energy efficiency, achieve efficient load balancing, and ultimately prolong the network's lifespan.

DECLARATION STATEMENT

Funding	No, I did not receive.
Conflicts of Interest	No conflicts of interest to the best of my knowledge.
Ethical Approval and Consent to Participate	No, the article does not require ethical approval and consent to participate with evidence.
Availability of Data and Material	Not relevant.
Authors Contributions	All authors have equal participation in this article.

REFERENCES

1. Quy, V.K., et al., Routing Algorithms for MANET-IoT Networks: A Comprehensive Survey. Wireless Personal Communications, 2022. 125(4): p. 3501-3525. https://doi.org/10.1007/s11277-022-09722-x
2. Safari, F., et al., 'The diverse technology of MANETs: A survey of applications and challenges. International Journal of Future Computer and Communication, 2023. 12(2). https://doi.org/10.18178/ijfcc.2023.12.2.601
3. Sahu, R., S. Sharma, and M. Rizvi, ZBLE: zone-based leader election energy constrained AOMDV routing protocol. International Journal of Computer Networks and Applications, 2019. 6(3): p. 39-46. https://doi.org/10.22247/ijcna/2019/49643
4. Sahu, V., N. Sahu, and R. Sahu, A Comparative Study on Routing Protocols: RIPng, OSPFv3 and EIGRPv6 and Their Analysis Using GNS-3. International Journal of Advanced Networking and Applications, 2023: p. 5775-5780. https://doi.org/10.35444/IJANA.2023.15104

5. Sahu, R., S. Sharma, and M. Rizvi, ZBLE: Zone Based Leader Selection Protocol. 2019. https://doi.org/10.5815/ijwmt.2019.04.02
6. Sahu, R., M. Rizvi, and M. Mishra. Routing overhead performance study and evaluation of zone based energy efficient multi-path routing protocols in MANETs by using NS2. 35. in 2021 International Conference on Advances in Technology, Management & Education (ICATME). 2021. IEEE. https://doi.org/10.1109/ICATME50232.2021.9732762
7. Seth, I., K. Guleria, and S.N. Panda, A comprehensive review on vehicular ad-hoc networks routing protocols for urban and highway scenarios, research gaps and future enhancements. Peer-to-Peer Networking and Applications, 2024: p. 1-33. https://doi.org/10.1007/s12083-024-01683-1
8. Sahu, V. and R. Sahu, Energy Efficient Multipath Routing in Zone-based Mobile Ad-hoc Networks: Mathematical Formulation. 2022. https://doi.org/10.5815/ijmsc.2022.03.04
9. AL-Hasani, B. and B. Waheed, Comparative study and performance investigation of MANET routing protocols. International Journal of Nonlinear Analysis and Applications, 2022. 13(2): p. 1953-1964.
10. Singh, S.K. and J. Prakash. Energy efficiency and load balancing in MANET: a survey. in 2020 6th International Conference on Advanced Computing and Communication Systems (ICACCS). 2020. IEEE. https://doi.org/10.1109/ICACCS48705.2020.9074398
11. Almeida, R., et al. Classification of load balancing in the internet. in IEEE INFOCOM 2020-IEEE Conference on Computer Communications. 2020. IEEE. https://doi.org/10.1109/INFOCOM41043.2020.9155387
12. Rao, G.B.N. and A.K. Tripathy, Energy aware routing through genetic algorithm and AOMDV in MANET. International Journal of Intelligent Systems and Applications in Engineering, 2024. 12(8s): p. 435-441.
13. Venugopal, K. and T. Basavaraju, Load balancing routing in RPL for the internet of things networks: a survey. International Journal of Wireless and Mobile Computing, 2023. 24(3-4): p. 243-257. https://doi.org/10.1504/IJWMC.2023.131315
14. Rai, S., et al. Optimizing Wireless Sensor Networks: Dynamic Load Balancing Strategy with AOMDV Routing. in 2024 3rd International conference on Power Electronics and IoT Applications in Renewable Energy and its Control (PARC). 2024. IEEE. https://doi.org/10.1109/PARC59193.2024.10486598
15. Osamy, W., et al., LBAS: Load Balancing Aware Clustering Scheme for IoT-based Heterogeneous Wireless Sensor Networks. IEEE Sensors Journal, 2024. https://doi.org/10.1109/JSEN.2024.3381852
16. Saad, W.K., et al., Handover and load balancing self-optimization models in 5G mobile networks. Engineering Science and Technology, an International Journal, 2023. 42: p. 101418. https://doi.org/10.1016/j.jestch.2023.101418
17. Mohammed, A., et al. Traffic and Energy Aware Load Balancing Routing Protocol for Multipath Mobile Ad-Hoc Networks. in 2023 6th International Conference on Engineering Technology and its Applications (IICETA). 2023. IEEE. https://doi.org/10.1109/IICETA57613.2023.10351353
18. Dholey, M.K. and D. Sinha, ACOLBR: ACO Based Load Balancing Routing in MANET. Wireless Personal Communications, 2022. 126(3): p. 2483-2511. https://doi.org/10.1007/s11277-022-09804-w
19. Chandravanshi, K., G. Soni, and D.K. Mishra, Design and analysis of an energy-efficient load balancing and bandwidth aware adaptive multipath N-channel routing approach in MANET. IEEE Access, 2022. 10: p. 110003-110025. https://doi.org/10.1109/ACCESS.2022.3213051
20. Hui, Z., et al. A review of gateway load balancing methods in connecting MANET into internet. in 2021 23rd International Conference on Advanced Communication Technology (ICACT). 2021. IEEE. https://doi.org/10.23919/ICACT51234.2021.9370742
21. Biradar, M.A. and S. Mallapure, Multipath Load Balancing in MANET via Hybrid Intelligent Algorithm. Journal of Information & Knowledge Management, 2024: p. 2450010. https://doi.org/10.1142/S0219649224500102
22. Patel, R.S. and P. Kamboj. An efficient delay-based load balancing using aomdv in manet. in Proceedings of First International Conference on Computing, Communications, and Cyber-Security (IC4S 2019). 2020. Springer. https://doi.org/10.1007/978-981-15-3369-3_7
23. Naseem, M., et al., EE-LB-AOMDV: An efficient energy constraints-based load-balanced multipath routing protocol for MANETs. International Journal of Communication Systems, 2021. 34(16): p. e4946. https://doi.org/10.1002/dac.4946
24. R, M. C., & Ramakrishna, M. (2019). An Assessment on Energy Efficient Protocols for MANETS. In International Journal of Engineering and Advanced Technology (Vol. 9, Issue 1, pp. 1556–1561). https://doi.org/10.35940/ijeat.a1349.109119
25. Energy Efficiency Analysis Between Green Computing and Cloud Computing. (2019). In International Journal of Recent Technology and Engineering (Vol. 8, Issue 3S2, pp. 254–258). https://doi.org/10.35940/ijrte.c1047.1083s219
26. Sharma, T., & Sharma, R. (2024). Smart Grid Monitoring: Enhancing Reliability and Efficiency in Energy Distribution. In Indian Journal of Data Communication and Networking (Vol. 4, Issue 2, pp. 1–4). https://doi.org/10.54105/ijdcn.d7954.04020224
27. An Optimized Model for Energy Efficiency on Cloud System using PSO & CUCKOO Search Algorithm. (2019). In International Journal of Innovative Technology and Exploring Engineering (Vol. 8, Issue 9S, pp. 138–144). https://doi.org/10.35940/ijitee.i1022.0789s19
28. G, M. M., & S, G. (2020). Power Minimization Architecture for Multimodal Biometric System using Cadence. In International Journal of Emerging Science and Engineering (Vol. 6, Issue 9, pp. 1–5). https://doi.org/10.35940/ijese.h2478.046920

AUTHOR'S PROFILE

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