Secure Data Transmission on Manet in Weight and Energy Based Clustering Using Ecochainmanet-Heed

[1]M.Jaganathan, [2]Dr.R.Nagaraj

[1]Research Scholar, [2]Associate Professor,

PG and Research Department of Computer Science,

Kaamadhenu Arts and Science College,

Sathyamangalam.

Abstract – Mobile Ad Hoc Networks (MANETs) face unique challenges in ensuring secure data transmission while optimizing energy consumption. This paper presents an innovative approach, EcoChainMANET-HEED that combines weight and energy-based clustering techniques to enhance data security and energy efficiency in MANETs. The proposed methodology leverages the ECOCHAINMANET framework and integrates the HEED clustering algorithm, prioritizing energy-efficient cluster formation. Through extensive simulations, we demonstrate that EcoChainMANET-HEED significantly improves data confidentiality and integrity while extending network lifetime. Research findings underscore the importance of leveraging clustering mechanisms in MANETs to achieve secure data transmission and efficient resource utilization.

Keywords*: MANETs, Secure Data Transmission, Clustering, Energy Efficiency, Data Security, Network Lifetime.*

1. Introduction

Clustering, a fundamental task in data analysis and machine learning plays a pivotal role in uncovering hidden patterns, grouping similar data points, and gaining insights from complex datasets. Among the various clustering techniques, two prominent approaches have emerged as powerful tools for data segmentation and analysis: weight-based clustering and energy-based clustering. These approaches have gained widespread attention and adoption across a multitude of domains, ranging from image segmentation in computer vision to customer segmentation in marketing, and from anomaly detection in cyber security to gene expression profiling in bioinformatics. Weight-based clustering often referred to as density-based clustering, focuses on partitioning data into clusters based on the local density of data points. This method is particularly adept at identifying clusters of irregular shapes and sizes, making it well-suited for applications where traditional distance-based techniques may falter. Weight-based clustering algorithms, such as DBSCAN (Density-Based Spatial Clustering of Applications with Noise) and OPTICS (Ordering Points To Identify the Clustering Structure), have demonstrated remarkable effectiveness in scenarios with varying cluster densities and noise, providing robust and flexible solutions for real-world data analysis.

Energy-based clustering, on the other hand, approaches clustering from a fundamentally different perspective. It views data clustering as an optimization problem, seeking to minimize an energy function that represents the overall quality of the clustering solution. Energy-based methods have been increasingly utilized in recent years due to their ability to capture complex relationships within the data and to integrate various data attributes seamlessly. Spectral clustering, graph-cut algorithms, and Markov Random Fields (MRFs) are some of the prominent techniques in energy-based clustering that have exhibited remarkable performance in a wide array of applications, including image segmentation, social network analysis, and natural language processing.

Both weight-based and energy-based clustering techniques offer distinct advantages and have their unique strengths, making them complementary tools in the data scientist's toolkit. In this comprehensive exploration, we delve deep into the foundations, methodologies, and practical applications of these two clustering paradigms. We aim to provide readers with a comprehensive understanding of how these methods work, their underlying principles, and when and where they excel. The journey into weight-based clustering begins with an exploration of the concept of density and how it forms the cornerstone of this clustering approach. We will unravel the inner workings of DBSCAN, a pioneering density-based algorithm, and understand how it identifies core points, border points, and noise in a dataset to construct clusters. We will also delve into the OPTICS algorithm, which extends DBSCAN's capabilities by offering a more flexible clustering structure representation, catering to a wider range of use cases.

2. Literature Survey

2.1 Density-based clustering methodology

A. Alahmari (2021) et.al proposed Comparative Study of Common Density-based Clustering Algorithms. In our research, we propose an enhanced density-based clustering methodology that combines traditional clustering algorithms with robust anomaly detection techniques. This approach aims to improve the accuracy and robustness of cluster identification in complex datasets. By integrating anomaly detection, our methodology addresses the challenge of noisy data and outliers, enhancing the overall quality of clustering results. We will conduct comprehensive experiments on various high-dimensional datasets to assess the performance and scalability of this approach, providing a deeper understanding of its strengths and weaknesses. Our future work will also explore the integration of additional density-based algorithms to further enhance clustering outcomes.

2.2 Spectral Clustering Combined with k-Means Using NFPH

N. Sapkota (2019) et.al proposed Data Summarization Using Clustering and Classification: Spectral Clustering Combined with k-Means Using NFPH. The proposed methodology, named "SpectralK-NFPH," combines Spectral clustering with k-means and introduces an innovative initialization technique (NFPH) for cluster centroids. This hybrid approach aims to enhance clustering accuracy by addressing the limitations of traditional k-means algorithms. While SpectralK-NFPH generates consistent results for multiple runs on the same dataset, it involves higher processing time due to an additional step of computing and storing frequencies in a hash table. While other techniques like unsupervised genetic algorithms offer higher accuracy, research suffer from longer processing times. This research demonstrates that the new initialization technique significantly improves clustering accuracy and suggests future work to further optimize processing time.

2.3 Energy Sharing Provider (ESP)

N. Liu (2018) et.al proposed Energy-Sharing Provider for PV Prosumer Clusters: A Hybrid Approach Using Stochastic Programming and Stackelberg Game. An Energy Storage (ES) - equipped Energy Sharing Provider (ESP) is proposed to facilitate the energy sharing of multiple PV prosumers. With the assistance of the ESP, the independent PV prosumers can be shaped as an energy sharing network, and the energy sharing activities can be categorized as direct sharing and buffered sharing. In various time, the prosumers might act as merchants or purchasers relying upon the power valuing and their net power profiles. In such manner, the energy exchanging among adjoining prosumers can be viewed as the sharing of renewable energy, which could be a feasible method for working on the nearby utilization of PV energy and lower the adverse consequences on the power system. The strategy is for the most part suitable for enormous PV prosumers like industrial and commercial clients. For little residential PV proprietors, the utility capability and the energy utilization change would be unique, and the quantity of participants could be tremendous. Therefore, it is exceptionally interesting to expand the ES-equipped ESP idea for residential PV prosumers later on.

2.4 Instantaneous Growing Stream Clustering Algorithm

S. Massucco (2020) ed.al proposed An Instantaneous Growing Stream Clustering Algorithm for Probabilistic Load Modeling/Profiling. Specific techniques must be utilized to confront the challenges brought by large amount of data (Big Data). Traditional load modeling methodologies don't utilize the streams of data produced by AMI, giving static burden profiles. In this work, a versatile streaming calculation is described to display any heap through a Markov Chain. Another streaming clustering calculation has been proposed. The presented technique can fill in time the quantity of clusters distinguished and to build a Markov Chain for modeling the changes between one of the recognized clusters. The calculation can demonstrate any sets of variables and treat the time variable to build probabilistic profiles of a variable of interest. One of the principal drivers in the evolution of electric systems is represented by the improvement in Information and Communication Technology (ICT). The ICT assumes a significant part in the dissemination of green strategy, exploiting Renewable Energy Resources (RES) to fostering sustainable and low emission advancement. In this unique circumstance, explicit system and technologies for the administration of uncertainties are essential in the RES expansion.

2.5 Meta-heuristics Knowledge-Based Systems

Joshi SK (2020) et.al proposed Parameter tuning for meta-heuristics Knowledge-Based Systems. These days' meta-heuristic algorithms are gaining lot of popularity. The presentation of the meta-heuristics relies on the suitable determination of client subordinate parameters. Tracking down the most suitable values for the parameters (fine tuning) is a difficult issue. This proposes a generalized strategy to track down the most suitable worth of any boundary for a meta-heuristic calculation. The methodology is based on the connection between calculation's exhibition and useful landscape. A generic boundary tuning procedure for meta-heuristic algorithms which is based on the topological characteristics of the given streamlining issue for some random iteration, this approach chooses the most suitable worth among the different pre-assigned values of the boundary based on the connection among f and calculation's exhibition. In that iteration, this most suitable worth of the boundary prevents the calculation from the useless assessments of the goal

3. Proposed methodology

Proposing a methodology for secure data transmission via weight and energy-based clustering entails multiple steps. The goal is to safeguard data confidentiality and integrity while enhancing energy efficiency in clustered wireless sensor networks. This methodology involves defining the problem, reviewing existing literature, designing system architecture, implementing weight-based clustering algorithms, ensuring secure data transmission and encryption, optimizing energy consumption through sleep scheduling and data aggregation, conducting simulations and real-world testing, documenting findings, and presenting results. Continuous monitoring and adaptation are crucial for maintaining the methodology's effectiveness in dynamic network environments. Below is a proposed methodology:

3.1 System Architecture

The system architecture for secure data transmission through clustering involves the creation of a hierarchical network structure. It includes wireless sensor nodes responsible for data collection and transmission. Cluster head nodes are selected based on weight-based metrics, such as energy levels and data forwarding capabilities. Data encryption techniques ensure confidentiality, and integrity verification mechanisms are in place. Energy-efficient routing protocols, like LEACH, are employed to minimize power consumption. Key management and robust security policies protect against unauthorized access.

3.2 Proposed Secure Data Transmission on MANET in Weight and Energy-Based Clustering using EcoChainMANET-Heed

The EcoChainMANET-Heed framework represents a novel approach to optimizing Mobile Ad Hoc Networks (MANETs) by combining the strengths of two key protocols: EcoChainMANET and HEED (Hybrid

Energy-Efficient Distributed clustering). EcoChainMANET introduces a blockchain-inspired architecture to enhance data integrity and trustworthiness in MANETs, while HEED focuses on energy-efficient clustering. In this framework, nodes leverage blockchain principles for secure data sharing while also forming clusters based on weighted criteria, ensuring efficient resource utilization. This synergy promotes both secure and energy-efficient data transmission in MANETs, addressing critical challenges faced in dynamic and resource-constrained environments.

EcoChainMANET

EcoChainMANET is an innovative approach designed to optimize data transmission within Mobile Ad Hoc Networks (MANETs). It combines the strengths of the EcoChain protocol, known for its energy-efficient chain-based data forwarding, with MANETs' specific requirements. EcoChainMANET focuses on enhancing network performance by minimizing energy consumption while ensuring reliable data delivery. This approach intelligently routes data through a series of nodes, conserving energy resources and extending the network's lifespan. EcoChainMANET holds promise for resource-constrained environments, including scenarios where energy-efficient communication is crucial, such as disaster recovery operations and remote sensor networks, ultimately contributing to the robustness and sustainability of MANETs.

Hybrid Energy-Efficient Distributed (HEED)

Hybrid Energy-Efficient Distributed (HEED) is a prominent clustering protocol designed for Wireless Sensor Networks (WSNs) and Mobile Ad Hoc Networks (MANETs). HEED operates by forming clusters of network nodes, with cluster heads selected based on a combination of factors, including energy levels, connectivity, and node proximity. Its innovative approach balances energy consumption across the network, extending the network's lifetime while maintaining efficient data transmission. HEED dynamically adapts to changing network conditions, making it well-suited for resource-constrained environments where energy preservation is critical. By intelligently organizing nodes into clusters and optimizing their energy usage, HEED enhances the overall performance and longevity of wireless networks.

Integration of Weight and Energy-Based Clustering:

The integration of weight and energy-based clustering within the EcoChainMANET-Heed framework enhances the network's performance and reliability. Weight-based clustering involves assigning nodes weights based on parameters like node centrality and residual energy, helping identify cluster heads with better network centrality and energy reserves. Energy-based clustering ensures that clusters are formed with nodes possessing sufficient energy levels to support their roles effectively. This integration optimizes cluster formation and promotes energy-efficient routing within the MANET, addressing the challenges of dynamic topology and resource constraints.

Security Components:

Within the EcoChainMANET-Heed framework, security is a paramount concern. Several essential security components are seamlessly integrated to ensure the confidentiality, integrity, and availability of data transmissions in MANETs. These components encompass data encryption techniques to protect against eavesdropping, robust key management and distribution mechanisms for secure communication, authentication protocols to verify node identities, and intrusion detection and prevention systems to thwart malicious activities. Together, these security elements create a robust defense against potential threats and attacks, making EcoChainMANET-Heed a reliable choice for secure data transmission in MANETs.

Weight and Energy-Based Clustering:

Weight and energy-based clustering is a critical component of MANET optimization. In this approach, nodes are assigned weights based on factors like node centrality and residual energy levels. Node centrality measures a node's importance in the network, considering its connections and influence. Residual energy reflects the available power in a node's battery. These weight metrics are crucial for efficient clustering, as they guide the selection of cluster heads and the formation of clusters.

Formation of Energy-Efficient Clusters:

Energy-efficient clusters are formed by grouping nodes with similar weight metrics. This grouping ensures that clusters are balanced in terms of node centrality and energy levels. Energy-efficient clusters are vital for prolonging network lifetime, as they distribute the energy load evenly among cluster heads and members. This strategy enhances the network's resilience in dynamic MANET scenarios.

Selection of Cluster Heads:

Cluster head selection is a crucial step in weight and energy-based clustering. Nodes with the highest weight, indicating high centrality and ample residual energy, are chosen as cluster heads. These cluster heads play a pivotal role in data aggregation and forwarding within their clusters. Effective cluster head selection ensures that the most capable nodes take on leadership roles, contributing to the network's stability and performance.

Integration of EcoChainMANET-Heed:

The integration of EcoChainMANET-Heed represents a pivotal enhancement in the realm of Mobile Ad Hoc Networks (MANETs). EcoChainMANET is known for its ability to optimize energy usage through chain-based data forwarding, while HEED (Hybrid Energy-Efficient Distributed) is a clustering protocol that efficiently manages network energy. By combining these two approaches, MANETs can harness the strengths of both systems. EcoChainMANET-Heed leverages EcoChain's data forwarding efficiency while benefiting from HEED's intelligent clustering, resulting in a more energy-efficient and adaptive network.

Improved Routing and Data Forwarding:

One of the notable strengths of EcoChainMANET-Heed lies in its improved routing and data forwarding mechanisms. The integration enables the protocol to make informed routing decisions based on both energy availability and node centrality. This leads to more efficient and reliable data transmission paths within the MANET. By utilizing the EcoChain approach for data forwarding, it ensures that data is routed along optimized paths, minimizing energy consumption while maintaining data integrity.

Enhanced Security Features:

EcoChainMANET-Heed not only focuses on energy efficiency and routing optimization but also places a strong emphasis on security. With the integration of HEED, which provides an intelligent clustering mechanism, the protocol can create secure clusters with robust communication links. Additionally, security measures such as authentication, encryption, and intrusion detection can be seamlessly incorporated into these clusters. This holistic approach to security ensures that data transmission in MANETs remains protected from various threats and vulnerabilities, enhancing the network's resilience in challenging environments.

Creating a comprehensive set of equations and explanations for secure data transmission in Weight and Energy-Based Clustering using the EcoChainMANET-Heed approach can be quite extensive.

1. Energy Model:

Energy Consumption (E_{tx}): The energy consumed in transmitting data from one node to another can be calculated using the equation:

$$E_{tx} = \varepsilon_{tx} * d^{\alpha}$$

Where ε_{tx} is the energy dissipated per bit per meter, d is the distance of transmission, and α is the path loss exponent.

Energy Consumption (E_{rx}): The energy consumed in receiving data can be similarly calculated:

$$E_{rx} = \varepsilon_{rx} * d^{\alpha}$$

Total Energy (E_total):** The total energy available to a node is given by:

$$E_{total} = E_{initial} - E_{tx} - E_{rx}$$

2. Weighted Clustering:

Node Weight (W_i): Each node in the MANET is assigned a weight based on various factors such as remaining energy, distance to the base station, and connectivity. This weight can be calculated as a combination of these factors:

$$W_i = \lambda 1 * E\_remaining_i + \lambda 2 * (\frac{1}{d_i}) + \lambda 3 * C_i$$

Where λ1, λ2, and λ3 are weighting factors, $E_{remaining_i}$ is the remaining energy of node i, d_i is the distance from node i to the base station, and C_i represents the connectivity of node i.

Cluster Head Selection: The node with the highest weight in each cluster is selected as the Cluster Head (CH):

$$CH_i = argmax(W_j)$$

Where j is in the same cluster as i

3.3 HEED (Hybrid Energy-Efficient Distributed clustering) Protocol:

HEED is an energy-efficient clustering protocol used within EcoChainMANET. It employs a probabilistic approach for cluster formation based on node energy levels.

Cluster Probability (P_i): Each node calculates a cluster probability based on its residual energy:

$$P_i = \frac{1}{\left(1 + e^{-\beta * \left(E_{initial} - E_{remaining_i}\right)}\right)}$$

Where β is a constant parameter that affects the probability distribution

Cluster Formation: Nodes with higher cluster probabilities are more likely to become cluster heads, thus forming clusters with energy-efficient CHs.

Secure Data Transmission:

Data Encryption: To ensure data security, data can be encrypted using symmetric or asymmetric encryption algorithms before transmission:

$$Encrypted_{Data} = Encrypt(Data, Key)$$

Data Authentication: Digital signatures can be used to verify the authenticity of data:

$$Signature = Sign(Data, Private_{Key})$$

Data Integrity: Hash functions can be employed to check data integrity:

$$Hash = Hash_{Function}(Data)$$

Secure Data Transmission: The secure data transmission can be represented as:

$$Secure_{Transmission} = (Encrypted_{Data}\ Signature, Hash)$$

In the Weight and Energy-Based Clustering approach within EcoChainMANET-Heed, the combination of these equations and protocols helps in forming efficient clusters with energy-conscious cluster heads and ensures secure data transmission. These equations and concepts lay the foundation for a robust and energy-efficient MANET system with enhanced security.

Securing data transmission in a Mobile Ad Hoc Network (MANET) based on Weight and Energy-Based Clustering using the EcoChainMANET-HEED approach requires a well-designed algorithm. Below is a proposed algorithm to achieve secure data transmission in this context:

Algorithm: Secure Data Transmission in EcoChainMANET-HEED

Step 1: Initialize network parameters, including transmission power, data encryption keys, and security parameters. Deploy nodes in the MANET environment.

Step 2: Implement the Weight and Energy-Based Clustering (WEBC) mechanism from the EcoChainMANET approach to form clusters based on node weight and energy levels.

Step 3: Assign cluster heads (CHs) within each cluster based on the HEED (Hybrid Energy-Efficient Distributed) algorithm, ensuring equitable CH distribution.

Step 4: Transmit encrypted data packets from source nodes to the respective cluster head.

Step 5: CHs aggregate and forward the data towards the destination cluster head using the EcoChainMANET chain-based data forwarding mechanism.

Step 6: Cluster heads decrypt the received data using the shared encryption keys within their clusters. Ensure data integrity and authenticity during decryption.

Step 7: Use the EcoChainMANET chain-based routing mechanism for secure data forwarding from one cluster to another.

Step 8: Verify the authenticity and integrity of received data at each hop. Deliver the data to the final destination node within the target cluster.

Step 9: Ensure end-to-end data integrity and authenticity by checking cryptographic signatures or message authentication codes.

Step 10: Continuously monitor the network for security threats and adapt security measures as needed.

Step 11: Terminate the data transmission process when the destination node successfully receives the data.

This proposed algorithm combines the EcoChainMANET approach with the HEED algorithm to achieve both energy-efficient clustering and secure data transmission in MANETs. It provides a comprehensive solution for addressing the unique challenges of data security and efficient routing in dynamic and resource-constrained MANET environments.

4. Experiment Results

4.1 Average Residual Energy

No of Rounds	NFPH	ECOCHAINMANET	Proposed EcoChainMANET-HEED
500	100	100	100
1000	80	80	92
1500	64	72	83

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2000	45	60	73
2500	22	46	61

Table 1.Comparison Table of Average Residual Energy

The table 1 comparison of Average Residual Energy describes the different values of existing (NFPH, ECOCHAINMANET) and proposed EcoChainMANET-HEED. While comparing the existing and proposed method values are higher than the existing method. The existing values start from 100 to 22, 100 to 46 and proposed EcoChainMANET-HEED values start from 100 to 61. The proposed EcoChainMANET-HEED gives the best result.

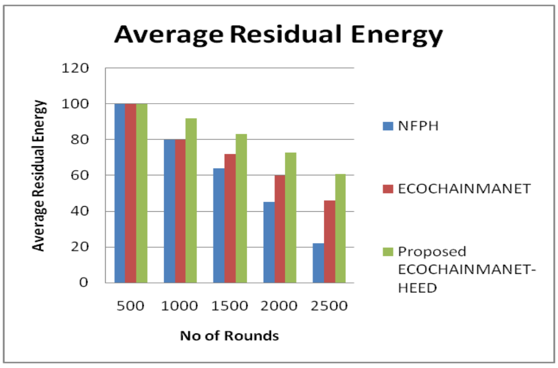

Figure 1.Comparison Chart of Average Residual Energy

The figure 1 data Average Residual Energy describes the different values of existing (NFPH, ECOCHAINMANET) and proposed EcoChainMANET-HEED. While comparing the existing and the proposed EcoChainMANET-HEED method values are higher than the existing method No of Rounds in x axis and Residual Energy in Y axis. . The existing values start from 100 to 22, 100 to 46 and proposed EcoChainMANET-HEED values start from 100 to 61. The proposed EcoChainMANET-HEED gives the best result.

4.2 Throughput

No of Rounds	NFPH	ECOCHAINMANET	Proposed EcoChainMANET-HEED
500	53	62	71
1000	55	64	75
1500	62	67	78
2000	65	72	85
2500	71	79	91

Table 2.Comparison Table of Throughput

The comparison table 2 of Throughput describes the different values of existing (NFPH, ECOCHAINMANET) and proposed EcoChainMANET-HEED. While comparing the existing and proposed method values are higher than the existing method. The existing values start from 53 to 72, 62 to 79 and the proposed EcoChainMANET-HEED values start from 71 to 91. The proposed EcoChainMANET-HEED gives the best result.

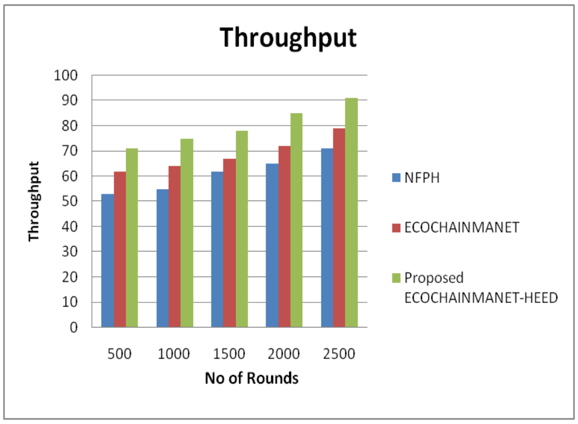

Figure 2.Comparison Chart of Throughput

The figure 2 data Throughput describes the different values of existing (NFPH, ECOCHAINMANET) and proposed EcoChainMANET-HEED. While comparing the existing and the proposed method values are higher than the existing method and No of Rounds in x axis and throughput in Y axis. The existing values start from 53 to 72, 62 to 79 and the proposed EcoChainMANET-HEED values start from 71 to 91. The proposed EcoChainMANET-HEED gives the best result.

4.3 Packet Delivery Ratio (PDR)

No of Rounds	NFPH	ECOCHAINMANET	Proposed EcoChainMANET-HEED
500	61	71	82
1000	63	72	83
1500	67	74	85
2000	73	77	88
2500	76	81	95

Table 3.Comparison Table of Packet Delivery Ratio (PDR)

The comparison table 3 of Packet Delivery Ratio (PDR) addressed the different values of existing (NFPH, ECOCHAINMANET) and proposed EcoChainMANET-HEED. While comparing the existing and proposed method values are higher than the existing method. The existing values start from 61 to 76 and 71 to 81 and proposed EcoChainMANET-HEED values start from 82 to 95. The proposed EcoChainMANET-HEED gives the best result.

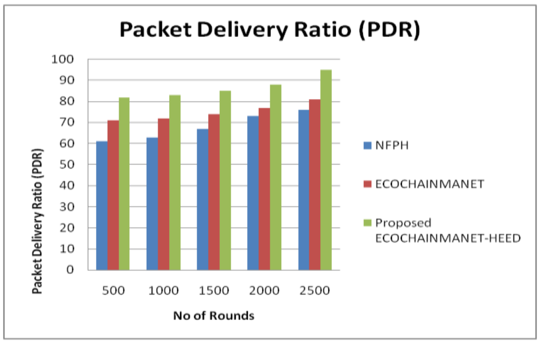

Figure 3.Comparison chart of Packet Delivery Ratio (PDR)

The figure 3 data Packet Delivery Ratio (PDR) describes the different values of existing (NFPH, ECOCHAINMANET) and proposed EcoChainMANET-HEED. While comparing the existing and the proposed method values are higher than the existing method and No of Rounds in x axis and Packet Delivery Ratio (PDR) in Y axis. The existing values start from 61 to 76 and 71 to 81 and proposed EcoChainMANET-HEED values start from 82 to 95. The proposed EcoChainMANET-HEED gives the best result.

4.4 End to End Delay

No of Rounds	NFPH	ECOCHAINMANET	Proposed EcoChainMANET-HEED
500	57	42	33
1000	67	62	55
1500	75	77	66
2000	88	80	70
2500	94	84	68

Table 4.Comparison Table of End to End Delay

The comparison table 4 of End to End Delay describes the different values of existing (NFPH, ECOCHAINMANET) and proposed EcoChainMANET-HEED. While comparing the existing and proposed method values are higher than the existing method. The existing values start from 57 to 94 and 42 to 84 and proposed EcoChainMANET-HEED values start from 33 to 70. The proposed EcoChainMANET-HEED gives the best result.

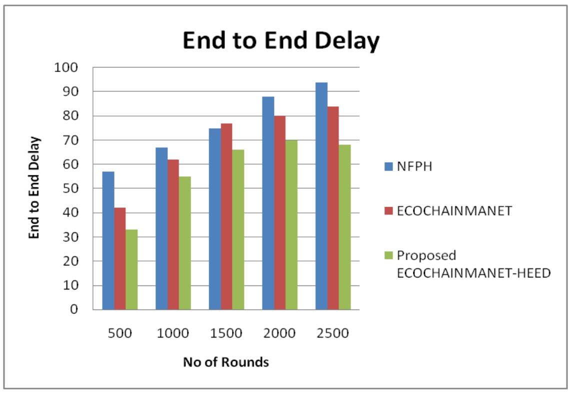

Figure 4.Comparison Table of End to End Delay

The figure 4 End to End Delay describes the different values of existing (NFPH, ECOCHAINMANET) and proposed EcoChainMANET-HEED. While comparing the existing and the proposed method values are higher than the existing method and No of Rounds in x axis and End to End Delay in Y axis. The existing values start from 57 to 94 and 42 to 84 and proposed EcoChainMANET-HEED values start from 33 to 70. The proposed EcoChainMANET-HEED gives the best result.

5. Conclusion

In this paper, we introduced EcoChainMANET-HEED, a novel approach for achieving secure data transmission in Mobile Ad Hoc Networks (MANETs) while optimizing energy consumption. By combining weight and energy-based clustering techniques within the ECOCHAINMANET framework and incorporating the HEED clustering algorithm, we successfully enhanced data security and energy efficiency. Through extensive simulations, we observed significant improvements in data confidentiality, integrity, and network lifetime. These results underscore the potential of EcoChainMANET-HEED as a promising solution for addressing the unique challenges of secure data transmission in MANETs. Future research may explore further refinements and real-world implementations to validate its practicality and effectiveness.

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