Towards the Development of Gaussian Clustering Algorithm Technology to Extend the Lifetime of MANETs

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ABSTRACT

Mobile Ad hoc Networks (MANETs) are infrastructure-independent wireless networks where nodes communicate directly or through relays without a central base station. Routing protocols employed in MANETs face numerous challenges due to their limited resources. Cross-layer optimization is fundamental to conserving energy and achieving quality of service parameters. However, reducing end-to-end diversity conflicts with power consumption, creating a problem when trying to improve network lifetime. In this work, a Lifetime Enhancement Routing (LER) protocol, which selects the most efficient path to the destination using residual energy and cost exchange metrics, is proposed. LER primarily reduces node overutilization and load to prolong the network lifetime. The proposed MANET performance optimization technique is Gaussian clustering algorithm with one of the deep learning (RNN) techniques as a combined technique. The simulation results show that the proposed protocol significantly reduced energy consumption and augmented the ability to send data through the best path available in the network with a high efficiency of up to 92%.

Keywords-wireless networks; Mobile Ad hoc Networks (MANETs); Vehicular Ad hoc Networks (VANETs); Quality of Service (QoS); efficient routing; smart vehicles; Artificial Intelligence (AI)

I. INTRODUCTION

The growth of the Web of Things and the enormous expansion in present-day correspondence advances have prompted an augmentation in the utilization of ad hoc networks focused on vehicles. Smart urban grids face transportation, correspondence, and energy challenges that can be addressed by implementing Mobile Ad hoc Networks (MANETs) [1, 2]. Completing an innovative and smart structure framework equips clients with a energy-saving strategy and a framework for accomplishing energy efficiency goals. Structure processing parts and smart home partner frameworks could help clients improve confidential satisfaction, and AI might simultaneously examine their approach to acting [3, 4]. The structure of a MANET allows nodes to communicate directly within their wireless range. However, due to limitations such as signal attenuation, environmental noise, and limited battery life, MANETs often have less capacity and range than wired networks. Also, data transmission across the network may require multiple hops from one node to another. The multi-hop nature of MANETs necessitates that each node functions dually as both a host and a router, taking on responsibilities for routing and forwarding packets and performing various network functions independently. This unique operational mode distinguishes MANETs from traditional wireless networks and underscores their remarkable adaptability and versatility in environments lacking traditional network infrastructure [5].

Authors in [6] proposed a clustering algorithm for efficient energy management in MANETs using the Imperialist Competitive Algorithm (ICA). The method reduces energy consumption and increases network lifetime by optimizing routing and preventing unnecessary reclustering. Results showed significant improvements in energy efficiency, network stability, and reduced overhead compared to traditional methods. Authors in [7] proposed the Bat Optimized Link State Routing (BOLSR) protocol to enhance energy efficiency in MANETs. The protocol, aimes to optimize route selection based on energy metrics. Experimental results show improved energy consumption, network lifespan, packet delivery, reduced delay, and minimized overhead compared to traditional methods. Authors in [8] developed a machine learning-based approach for efficient clustering and QoS improvement in MANETs using Particle Swarm Optimization (PSO). The technique optimizes cluster head selection based on node mobility, energy utilization, and bandwidth, resulting in enhanced network throughput, reduced delay, and improved energy efficiency. Authors in [9] proposed an optimized routing protocol for MANETs that integrates Ant Colony Optimization (ACO) with Harmony Search Algorithm (HSA) to reduce energy consumption. The approach considers distance, residual energy, and hops to select the most energy-efficient path for data transmission. Experimental results show that the ACO-HSA method significantly improves energy efficiency and network lifespan compared to traditional routing protocols.

Authors in [10] developed a new routing protocol called IRDFPR-CMDNN to improve energy efficiency and data transmission reliability in MANETs. The protocol leverages machine learning techniques, including deep neural networks and probit regression, to select optimal paths and reduce energy consumption while enhancing data delivery rates and minimizing routing delays. Experimental results demonstrated that the protocol effectively improves data delivery, increases throughput, reduces energy consumption, and lowers packet loss rates and delays compared to conventional methods. In [11], a topology control algorithm to improve the performance of 5G-based MANETs by flexibly adjusting the coverage radius, is presented. The system aims to enhance energy efficiency and network reliability. The results showed that the proposed algorithm significantly enhances energy efficiency and improves the packet delivery ratio. The findings highlight the importance of topology control in improving the performance of 5G-based networks. Authors in [12] presented a comprehensive study on routing protocols and data transmission in Mobile Wireless Sensor Network (M-WSN) environments. The study focused on improving energy efficiency using reinforcement learning and AI techniques. The results showed significant improvements in energy efficiency and network reliability. The study highlights the substantial benefits of modern techniques to enhance mobile wireless network performance. Authors in [1] reviewed an improved protocol for enhancing energy efficiency in MANETs using reinforcement learning. The system aims to reduce energy consumption and increase packet delivery ratio. Experiments showed that the proposed protocol significantly enhances energy efficiency compared to traditional methods. The results indicate the substantial benefits of using reinforcement learning to improve network performance. Authors in [13] discuss a system for detecting attackers and optimizing routing using swarm intelligence-based Q-learning in MANETs. The system aims to enhance security and energy efficiency by optimizing routes. The results showed that the proposed system significantly reduces energy consumption and improves the packet delivery ratio. The findings indicate the importance of swarm intelligence in enhancing network performance. Authors in [14] reviewed deep reinforcement learning techniques to improve energy efficiency and performance in M-WSNs. The system focuses on balancing energy consumption and increasing data transmission productivity. Experiments showed that the proposed model significantly enhances energy efficiency compared to traditional methods. The results highlight the substantial benefits of deep learning in improving wireless sensor network performance. Authors in [15] reviewed the improvement of cluster-based routing in MANETs using energy prediction through enhanced deep learning techniques. The proposed system aims to improve energy efficiency and increase the packet delivery ratio. Experiments showed that the proposed model significantly enhances energy efficiency compared to traditional methods. The results confirm the effectiveness of deep learning in improving ad hoc network performance.

This paper presents the Lifespan Enhancement Routing (LER) protocol, a unique approach in enhancing network lifespan in MANETs, that chooses the most effective path based on cost trade-offs and residual energy indicators. LER effectively tackles the problem of striking a balance between lowering energy usage and end-to-end delivery, which lowers node overutilization and increases network longevity. The main novelty of this work is the combination of deep learning RNN technology and the Gaussian clustering technique, which improves the protocol's capacity to optimize network resource management. The proposed model achieved higher efficiency compared to previous studies thanks to the proposed integrated technique that reduces delays and errors.

II. METHODOLOGY

The proposed model is designed as an embedded architecture to improve the performance of MANET systems. The Gaussian clustering algorithm is the nominated technique for MANET performance enhancement.

A. *Nominated Clustering Techniques*

The model should implement an efficient clustering algorithm to save energy in mobile WSNs. The agglomeration mechanism of the proposed model structure is illustrated in Figure 1.

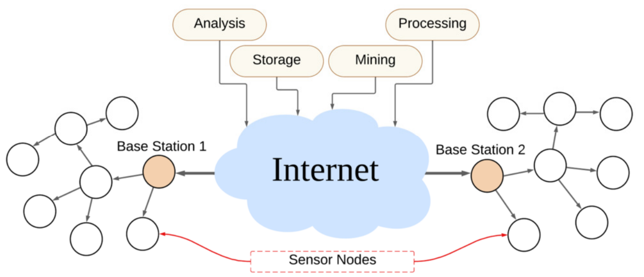


Fig. 1. Structure of the clustering techniques in WSN systems.

The main task of the proposed clustering technology is to overcome dispersion and power loss within the mobile WSN, which results from battery consumption and the difficulty of providing continuous power sources, especially for mobile sensors. Because clustering algorithms are unsupervised techniques, solving the problem depends on the algorithm gaining experience by evaluating identical problems as a training procedure. Several types of clustering algorithms provided in the literature can be divided into two main categories, namely, hard clustering and soft clustering [16].

In this work, the proposed technique is the Gaussian mixture algorithm, characterized by its high efficiency in forming cluster rings around the moving nodes in the WSN. Hence, each node is assigned to a group based on its probability of belonging to a certain center, and in order to improve the clustering process, the optimal estimates of the Gaussian distribution coefficients are used, which allows for managing the network resources with high efficiency. It tries to reduce unnecessary communication processes between nodes, thus improving energy consumption. It was chosen due to its high flexibility in dealing with complex and multidimensional data due to its use of the Maximum Expectation (EM) algorithm. The Gaussian mixture algorithm satisfies the following equations [17]:

$$P(x_i) = \frac{1}{2\pi\sigma^2} e^{\frac{(x_i-\mu_i)^2}{2}} \quad (1)$$

where x_i, is a random variable, σ^2 is the variance, and μ_i is the mean value:

$$\sigma^2 = \frac{1}{N}\sum_{i=1}^{N}(x_i - \mu_i)^2 \quad (2)$$

$$\mu_i = \frac{1}{N}\sum_{i=1}^{N} x_i - \mu_i \quad (3)$$

$$CRu(t) = (1-\eta)RCold + \eta \times RCnew \quad (4)$$

The probability of finding a certain cluster set of nodes is based on the random node variable x_i and the overall WSN nodes variance and mean. The Gaussian clustering for an N-node WSN is shown in Figure 2.

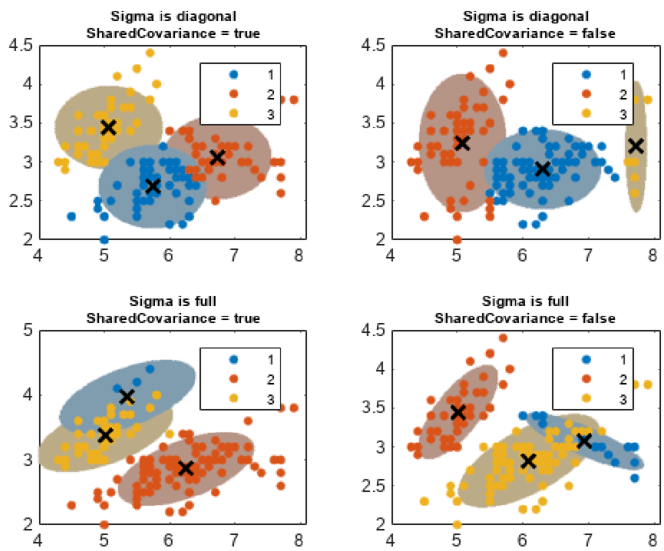


Fig. 2. Structure of the Gaussian clustering algorithm for WSNs.

The design parameters and values necessary to implement the proposed technique are listed and discussed in this section. The flowchart in Figure 3 demonstrates the operation of the proposed model. The proposed model initially prepares the datasets and reads them using the Read the Dataset option utility. Next, the MATLAB script codes are employed, which provide the necessary clustering algorithm programming tools. The proposed model starts with forming the MANET and distributing the nodes and the connections between them. Then, the process of estimating the neighboring nodes is carried out based on the Received Signal Strength (RSSI) in order to determine the optimal connection. Then, the packet identifiers and their temporal order are verified to ensure reliability. The trust rate for each node is calculated based on its record in dealing with data packets. Then, the nodes that have high trust values are selected to be used in the routing operations, with continuous updating of these values. Finally, the energy consumption of the nodes is calculated and the optimal paths in the network are chosen. The proposed deep learning technique in this work is the RNN because it has a storage memory that allows it to process sequential time data by passing the data from one time step to another, which makes it effective in analyzing temporal patterns. The weights are updated via the back-propagation process in time (BPTT) in order to learn the complex relationships between successive inputs, which allow it to accurately predict and improve decision-making.

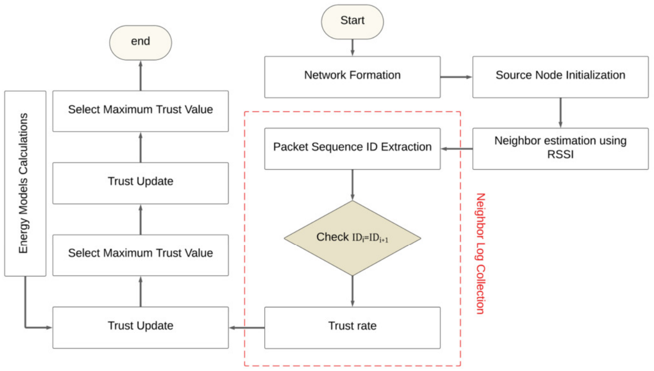


Fig. 3. Flowchart of the proposed methodology.

The clustering algorithm works on the RNN model as a combined technique, where data are generated and then the clustering process is performed on them. More precisely, it works on clustering the input layers, which are nodes in the network, and then works on coordinating these nodes (clustering) in the hidden layer, after which we get the results from the output layer. After that, the accuracy of the leakage detection is determined from the classification and training results of the deep learning algorithm. Finally, the overall steps are checked, and the processing ends. This technology is used in many practical fields, such as Time Series Analysis in Financial Markets and Cyber Threat Detection. The most important feature of this technology is the temporal memory, as it retains information from previous inputs and uses it to process subsequent inputs. This technology is designed to deal with temporal sequences. Simulations were run in Matlab environment. The conducted simulation specifications are shown in Table I. The proposed MANET WSN model was implemented in MATLAB code written to simulate the data communication through the model with the specified nodes and energy values.

TABLE I. SIMULATION SPECIFICATIONS

Round Iterations	Node Number	Minimum Energy	Maximum Energy
25	20	10	100
250	25	10	100
2500	30	10	100

B. Dataset

The data used in the project do not belong to real datasets but are derived programmatically using software models to simulate the proposed network coordinates of the MANET. These data were imported from the data processing tools function library in Matlab and are the coordinates of the wireless nodes used to generate and create the MANET cloud network, which will be simulated. Furthermore, the N=100 hub sum is employed for the MANET process against P=3 as the employed processor sum.

III. RESULTS AND DISCUSSION

A. Results

The results were recorded for each simulation by implementing the proposed model according to the design specifications and requirements. The simulated Gaussian clustering algorithm is reviewed according to the dataset that supports the generated MANET WSN nodes. Figure 4 shows a screenshot of an implemented MANET WSN with 20 nodes and minimum energy node distribution. The Gaussian mixture algorithm was employed to create clustering regions inside the MANET WSN structure, as shown in Figure 5.

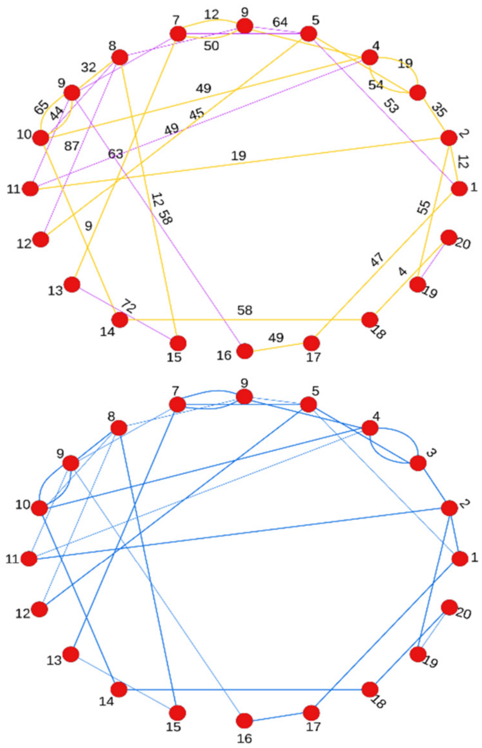


Fig. 4. Implemented MANET WSN with minimum energy node distribution.

The clustering head node is selected randomly to start the collection of the near nodes and form random clusters. This operation is repeated until the algorithm reaches the best cost function. Cost function refers to the optimal requirements for distance and energy consumption issues. Clustering is repeated because the sensors are movable, and other clusters are formed until the best cost function satisfies the minimal distances among nodes with the head base station node and the minimal energy consumption. The efficient Gaussian clustering algorithm is applied, which improves the energy efficiency of the WSN nodes and reaches optimal results. Figure 6 shows the final distribution of the active nodes within the MANET WSN model and their ideal paths produced by the clustering mechanism.

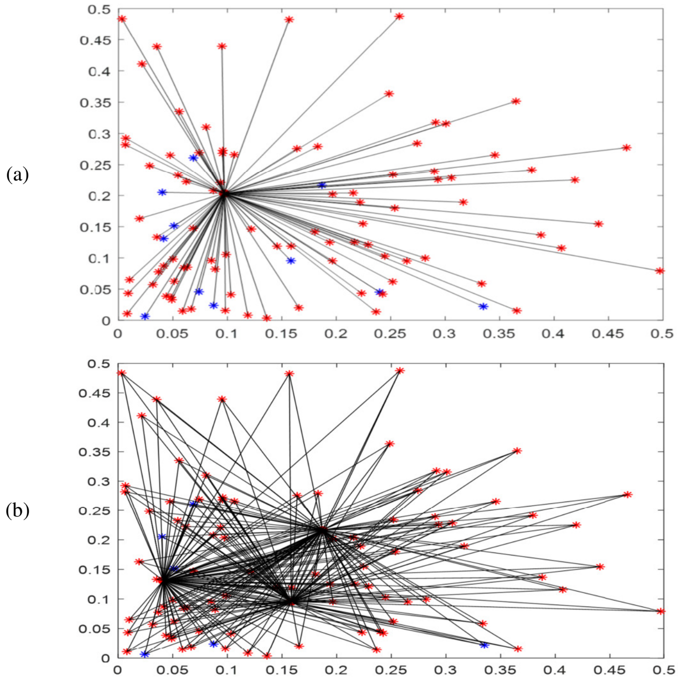


Fig. 5. (a) Gaussian clustering, (b) searching clustering.

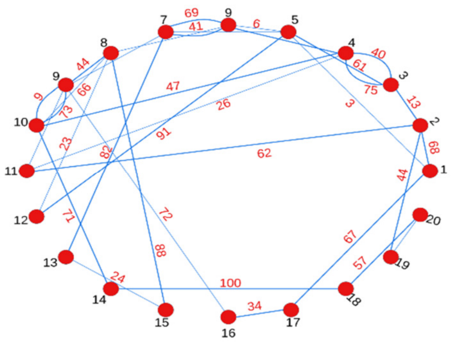
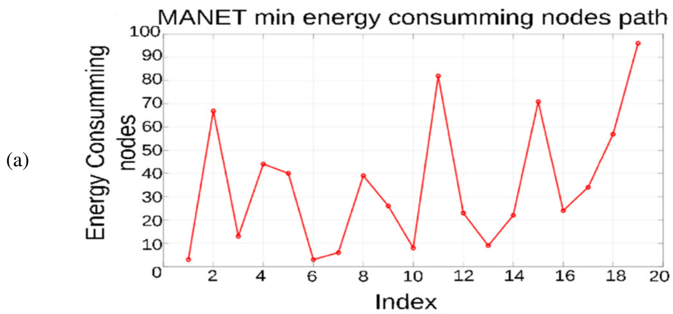


Fig. 6. MANET energy-efficient shortest paths.

The maximum and minimum energy values consumed from every node are shown in Figure 7, while Figure 8 presents the power consumption operating curve of the mobile MANET WSN.



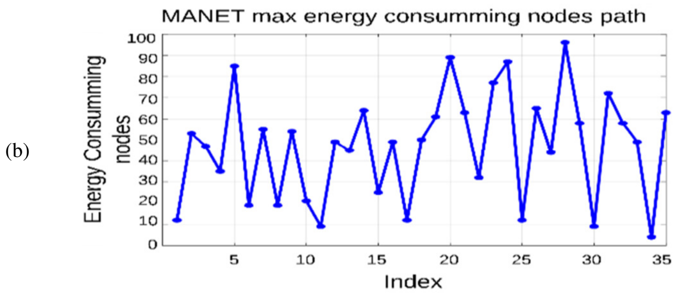


Fig. 7. (a) Minimum, and (b) maximum resulting energy consumption nodes paths of the MANET WSN model.

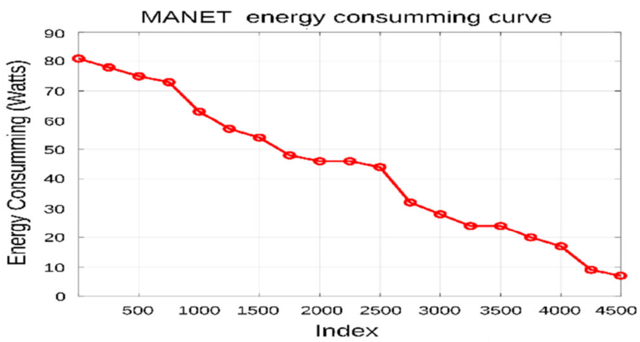


Fig. 8. Optimized energy consumption and performance in MANETs.

The proposed model shows that the overall energy consumed by the MWSN model starts with a high value of more than 85%, which is then minimized with the number of program iterations until it reaches the minimal value of less than 5%. Figure 9 shows the MANT WSN's final structure according to the optimal node's energy consumption.

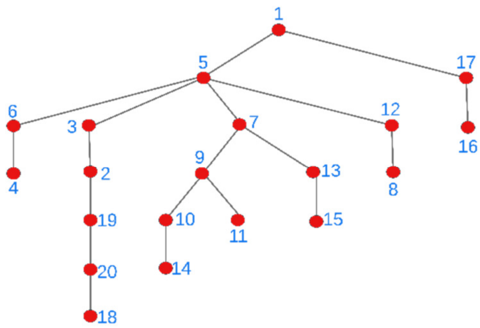


Fig. 9. MANT WSN final structure achieved according to the optimal consumed node energy.

B. Result Validation and Discussion

The proposed model was applied to study the development of an effective technique to extend the network's life in MANETs. It tries to find the best path between wireless nodes and increase the number of data sent through the transmission channel, while reducing the consumed energy of the nodes to the best level. A virtual MANET network system was simulated to test the Gaussian modulation and clustering technique, and self-powered network nodes were simulated to test the proposed optimization model using the Gaussian clustering algorithm. The results showed that the proposed technique showed improvement in reducing energy and finding the best path in the network with an efficiency of up to 92%, due to the utilized RNN technology that works on prediction and reduces the operational errors while suppressing interference. Table II shows the advantages and disadvantages of the proposed model.

TABLE II. ADVANTAGES AND DISADVANTAGES OF THE PROPOSED MODEL

Advantages	Disadvantages
Efficient node energy consumption reaches 50%	Difficulty in updating sudden node location changes
Efficient Gaussian clustering algorithm training with accuracy up to 92%	Accumulated error for long-time clustering
Suitable processing delay	Complicated structure for large MANET models
High data rate efficiency	More cost for more MANET nodes

IV. CONCLUSION AND FUTURE WORK

This article presents a feasible method to extend the lifetime of an MANET. The network demonstrated a remarkable energy decrease of up to 95%. The simulation results showed that the proposed Gaussian clustering algorithm can reduce energy consumption in addition to the possibility of increasing the data sent through the best path available in the network with an efficiency of up to 92%. The cost and delay efficiency of the proposed algorithm depend on its prediction capability to determine the optimal clusters.

Researchers can concentrate on different grouping, bunching, and crossover procedures in addition to the examined AI algorithms to compare the outcomes achieved with those of our proposed model.

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