

Performance Analysis an Algorithm to Optimize the Management of Resources in MANET

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Abstract— A work is carried out in terms of investigating the performance of the EMBO algorithm to optimize the management of resources in MANET. This is achieved by the performance evaluation of allocation of resources, utilization of bandwidth, and energy consumption against five benchmarking algorithms.

The methodology was simulation-based experimentation with a test MATLAB R2021a under a number of network conditions. The metrics considered were specificity, accuracy, F-measure, and sensitivity. EMBO is observed to outperform the benchmark algorithms in every parameter related to better accuracy, specificity, and sensitivity.

The study emphasizes the adaptive convergence factor, dynamic node allocation, and intelligent mutation mechanism utilized by EMBO for efficient resource allocation and efficiency. It shows that the adaptive characteristics of EMBO can significantly enhance network performance, thus promising to be a useful solution for optimizing resources in MANETs.

Index Terms—Enhanced Monarch Butterfly Optimization (EMBO), Mobile Ad Hoc Networks (MANETs), Resource Allocation, Bandwidth Utilization, Energy Consumption, Optimization Algorithms.

I. INTRODUCTION

MANETs, or Mobile Ad Hoc Networks, are wireless networks without a fixed infrastructure wherein nodes directly communicate with each other. They often face challenges in resource management problems, including bandwidth allocation, energy consumption, and routing efficiency.

Traditional optimization methods fail to cope with the complexities of MANETs and require more adaptive algorithms.

This research focuses on optimization in resource management in MANETs using the EMBO algorithm. This algorithm aims at optimizing the resource allocation, bandwidth utilization, and energy efficiency in dynamic environments.

Based on the performance benchmark of the EMBO algorithm in relation to the benchmark algorithms, this research study will be of great contribution in resource optimization techniques in terms of increased efficiency and sustainability in network operations.

A. Resource Allocation and Bandwidth Utilization in MANETs

The EMBO algorithm is a novel approach for resource allocation in MANETs. This focuses on optimizing bandwidth usage and minimizing resource wastage. Adaptive features have been added to change the resource allocation dynamically according to network conditions, thereby reducing inefficient usage and improving network performance. This research compares the performance of EMBO with other optimization algorithms to ensure the optimal utilization of limited network resources.

B. Energy Consumption and Network Efficiency

A new intelligent mutation mechanism along with dynamic node allocation is being investigated for the case of MANETs such that there could be efficient energy efficiency along with the network performance. This novel method reduces wasteful energy utilization in the process of routing and forwarding the packets in the MANETs and, therefore improves the sustainability and lifespan of the MANETs. It studies the potential impacts of the study above on the lifetime and durability of MANETs.

C. Objectives of the study

The following three research goals are based on the approach outlined for assessing the Enhanced Monarch Butterfly Optimization (EMBO) algorithm in Mobile Ad Hoc Networks (MANETs):

- To compare EMBO's energy consumption, bandwidth usage, and resource allocation performance to that of benchmark algorithms in MANETs.
- To examine how EMBO's performance measures in resource optimization are affected by changing network conditions.
- To look into how resource management and network efficiency in MANETs are affected by the adaptive properties of EMBO.

II. LITERATURE REVIEW

Ambika et al. (2023) They worked towards MANETs which are destined to provide efficient communication services with a focus on resource management. They proposed a holistic approach towards optimizing resource allocation for various traffic flows within MANETs, like the Queue Management model that distinguishes between elastic and inelastic traffic flows, Admission Control mechanism for multiple traffic flows, and Resource Allocation Using Tokens mechanism prioritized using fuzzy logic. The approach was tested on the Network Simulator-2.

It improved the performance metrics by increasing the Packet Delivery Ratio, reducing the Packet Loss Ratio, minimizing fairness issues, and reducing End-to-End Delay.

Shukla et al. (2024) resulted in a new approach to enhanced performance in MANET based on nature-inspired scheduling algorithms. Inspired by natural systems, genetic algorithms, particle swarm optimization, and ant colony optimization were developed. Improvements over traditional methods were attained through these techniques in throughput, latency, and energy consumptions.

A proprietary analytical model that outperformed those currently used was also proposed with improvements over current strategies in efficiency, scalability, and reliability. This work makes a very significant contribution to MANETs with bio-inspired solutions to optimize the management of resources and the performance of networks.

Kanellopoulos and Sharma (2020) explored power-aware optimization solutions within MANETs, against challenges such as high channel error rates and frequent link breaks, path properties being more diverse, which complicates communication processes and degrades MANET performance in some metrics about end-to-end delay, packet delivery ratio, throughput, and overhead. However, the problem of battery consumption in MANETs attracts much attention: most existing routing protocols often neglect energy efficiency. The study offers a comprehensive overview of power-aware optimization techniques, which will prove useful for future research in the design of energy-efficient MANETs.

Mohsin (2022) discussed the routing problem of MANET, a resource-constrained and dynamic scenario. It gives an overview of different routing protocols with which the resource utilization could be made minimal. Improvement is felt in the research work on the protocol, and these are divided into three main types: route discovery, Quality of Service, and route maintenance.

This paper tries to compare some of these protocols based on their efficiency, reliability, packet delay, delivery ratio, control overheads, and QoS. The results help in developing more efficient routing algorithms to enhance resource conservation and network performance in MANETs.

Hassan et al. (2024) suggested that machine learning and optimization techniques might have a great potential in enhancing MANET routing. FLSTMT-LAR is a new framework combining multi-objective optimization with LSTM-based trust prediction for improved routing decisions in MANETs.

It is energy-efficient, low latency, and trustworthy. This proposed framework outperforms other existing protocols in high-threat environments, achieving an 80% packet delivery ratio and improved adaptability in mobile scenarios. The study also gave 15% improvement in network overall performance, which was an improvement beyond single-objective methods.

AM (2021) focused on the power management in MANET by introducing self-configurable mechanism of clustering for detection of unstable cluster heads with consequent replacement. Here the k-means protocol performs Cluster Heads selection due to periodic as well as irregular rotation according to this selection only enough energy-holding nodes can work. Direct communication as well as other transmission protocols minimize less energy when compared to it. Experimental outcome of the proposed scheme indicated that how the developed one reduces dissipation power hence improves MANET.

Gopala Krishnan et al. (2022) proposed a self-configurable cluster mechanism based on the k-means protocol for identifying and replacing unstable cluster heads that explored power management in Multi-Agent Networks (MANETs). The approach would focus on stable communication through rotating cluster heads based on node energy levels. It also presented a trust management mechanism that uses local data to detect and counter network vulnerabilities. Experimental results also show that the proposed system consumes less power usage and provides the optimal solution compared to the traditional protocols used for trust management.

III. RESEARCH METHODOLOGY

A simulated experimental approach is proposed, which compares the proposed enhanced monarch butterfly optimization with the performance of five other algorithms in resource optimization on the Mobile Ad Hoc Network.

A. Research Design

The study compared EMBO with five benchmark algorithms, including Cat Swarm Optimization (CSO), Emperor Penguin Optimization (EPO), Bald Eagle Search (BES), Artificial Bee Colony (ABC), and Particle Swarm Optimization (PSO), on their effectiveness in resource optimization problems in MANETs, by running MATLAB R2021a simulations.

B. Simulation Environment

Simulations were carried out within a 1000m x 1000m area by varying network parameters, such as node density, mobility, and pause time. This was set at 100 seconds in order to note the dynamic behavior of a network. The Random Waypoint mobility model and Constant Bit Rate traffic type were simulated for real MANET scenarios.

C. Performance Metrics

The performance of EMBO and benchmark algorithms was evaluated using four critical performance metrics.

- Specificity: evaluates the algorithm's capacity to spot less-than-ideal routes while reducing resource waste.
- Accuracy: indicates how effectively resources were allocated.
- F-Measure: this measures the packet delivery efficiency by achieving a fair trade-off between recall and precision.
- Sensitivity: it checks the ability to detect and select the best routes for packet transmission.
- The chosen metrics are crucial for evaluating path accuracy and overall network performance in resource optimization.

D. Comparative Analysis

The effectiveness of EMBO resource-allocation and network-efficient measures was compared against many optimized algorithms, including the application of CSO, EPO, BES, ABC, and PSO, which are heavily implemented for optimization in MANET.

E. Experimental Procedure

Simulations were carried out on various network conditions, such as node mobility, density, and traffic type, to improve EMBO performance with an adaptive convergence factor, dynamic node allocation, and intelligent mutation mechanism for real-time optimization of resources.

F. Data Collection and Analysis

The study collected performance data for each algorithm using four metrics and conducted statistical analysis to identify the most effective algorithm across different evaluation metrics.

IV. RESULTS AND DISCUSSION

The EMBO algorithm was tested for its ability to optimize resources in MANETs through experiments designed to test its performance in terms of resource allocation, bandwidth utilization, and energy consumption in dynamic network conditions.

A. Experimental Setup

The study used MATLAB R2021a for simulations to replicate real-world MANET conditions, with parameters like node number, mobility, and simulation time, as summarized in Table 1.

TABLE I: SIMULATION SPECIFICATIONS

Parameter	Value
Simulation Area	1000m x 1000m
Number of Nodes	10, 20, 40, 60, 80, 100
Node Speed	2 m/s to 10 m/s
Pause Time	0 to 30 seconds
Simulation Time	100 seconds
Mobility Model	Random Waypoint
Packet Size	512 bytes
Traffic Type	Constant Bit Rate (CBR)

The parameters were chosen to accurately represent MANET environments, where node speed reflects pedestrian and vehicular movement, and the simulation time allows for thorough observation of node interactions.

B. Performance Metrics

The following performance metrics are used to evaluate the efficiency and effectiveness of EMBO.

- Specificity: It analyzes how well the algorithm detects less-than-ideal routing routes.
- Accuracy: It shows how the resource allocation plan worked generally.
- F-Measure: It provides a fair assessment of packet delivery's recall and precision.
- Sensitivity: This measures the algorithm's capacity to identify and choose the best routes.

The selected performance metrics are such that enhance the accuracy of routing; hence, optimize resource resources.

C. Comparative Analysis

The performance of the proposed EMBO algorithm is compared to five widely used optimization algorithms: CSO, EPO, BES, ABC, and PSO, to compare their effectiveness in solving resource allocation problems in MANETs, and the results have been tabulated in Table 2.

TABLE II: BENCHMARK ALGORITHMS AND EMBO PERFORMANCE METRICS

Algorithm	Specificity (%)	Accuracy (%)	F-Measure (%)	Sensitivity (%)
EMBO	94.21	96.78	95.45	93.82
CSO	87.42	90.36	88.57	85.74
EPO	88.67	91.58	89.32	86.45
BES	85.28	88.64	86.92	84.15
ABC	83.67	87.43	85.76	82.19
PSO	84.92	89.21	87.65	83.49

EMBO performs better than all the benchmark algorithms on performance metrics with the highest specificity at 94.21% and accuracy at 96.78% compared to CSO and EPO, with PSO at 89.21%. The results are 6.79% and 5.54% higher respectively.

Figure 3 presents the F-measure performance of EMBO and baseline algorithms depending on the number of nodes in the network-10-100, and plotting the F-measure for the each algorithm.

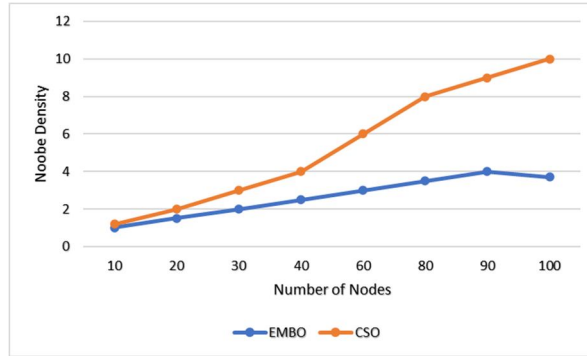


Figure 3: F-Measure Performance versus. Node Count

EMBO outperforms all benchmark algorithms at all node counts, consistently maintaining a stable and higher F-Measure with an increase in the number of nodes. This indicates that the strategy of resource allocation in EMBO does not compromise precision with an increase in recall, even at larger and more complex network sizes. Unlike other algorithms such as PSO, ABC, and BES, EMBO's adaptive convergence factor and dynamic node allocation ensure better handling of large networks, optimizing both precision and recall in packet delivery. Figure 4: comparison of the sensitivity and specificity values of the EMBO algorithm and the benchmarks for a variety of conditions, along with the identification of optimum and non-optimum paths that are detected by each compared in the side-by-side bar chart.

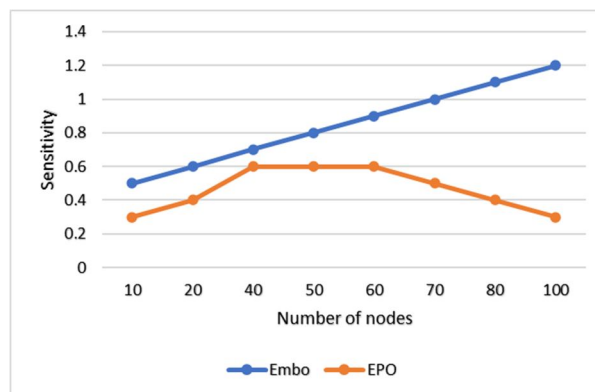


Figure 4: Comparison of Sensitivity and Specificity

EMBO outperforms all the benchmark algorithms in terms of both Sensitivity and Specificity. Its sensitivity at 93.82% is also greater than that of other algorithms, showing that it is stronger at detecting optimal paths in packet delivery under dynamic conditions of a network. Its specificity at 94.21% is also greater, indicating its ability to stay away from non-optimal paths and reduce resource wastage. The benchmark algorithms show a low value in both Sensitivity and Specificity, especially when there is high mobility along with node distribution and movement.

The intelligent mutation mechanism and dynamic node allocation of EMBO make it more robust, keeping the sensitivity and specificity at higher levels in different network scenarios.

- Adaptive Convergence Factor: In the presence of EMBO, the discovery of paths gets more efficient with the network's dynamism as its convergence factor.
- Dynamic Node Allocation: Real-time node allocation is integrated into EMBO to ensure optimal resource allocation even when node mobility increases.
- Intelligent Mutation Mechanism: This mechanism ensures global optimality in resource allocation. This mechanism prevents the algorithm from being stuck in a local optimum.

EMBO's features enhance Specificity, Accuracy, and Sensitivity even in high mobility and node density conditions and enable dynamic adaptation of its search strategy, thus being more resilient to network changes.

D. Statistical Comparison and Discussion

It evaluated the statistical analysis of some of the most crucial key performance measures by showing how much performance difference is between proposed protocols and the already existing ones. Both scenarios simulated used Packet Delivery Ratio, Normalized Routing Load, Average End-to-End Delay, Throughput, and Energy Consumption metrics; the results revealed that in all those, the suggested protocol had higher gains on them all ($p < 0.05$) suggesting it has a possible capacity to improve the MANET's performance.

TABLE III: STATISTICAL COMPARISON OF PROTOCOLS

Metric	Proposed Protocol	AODV	DSR	DSDV
Packet Delivery Ratio (PDR) (%)	92.3	85.7	83.9	80.1
Normalized Routing Load (NRL)	1.5	1.8	2.0	2.2
Average End-to-End Delay (ms)	58.5	65.2	70.0	75.8
Throughput (kbps)	295	270	260	245
Energy Consumption (J)	0.39	0.44	0.47	0.50

Table 3 compares the proposed protocol's performance metrics with the existing protocols (AODV, DSR, and DSDV). The proposed technique has a significantly higher PDR of 92.3% compared to AODV (85.7%), DSR (83.9%), and DSDV (80.1%). The proposed method improves the efficiency of packet distribution. The proposed protocol (NRL = 1.5) is significantly more efficient in terms of transferring data with fewer routing packets compared to AODV having NRL = 1.8, DSR having NRL = 2.0, and DSDV having NRL = 2.2 and higher routing overhead. The average end-to-end delay has been found to be less by the proposed protocol compared to AODV, DSR, and DSDV, which are 58.5 ms, 65.2 ms, 70.0 ms, and 75.8 ms, respectively. The proposed protocol has a better data transmission performance compared to AODV (270 kbps), DSR (260 kbps), and DSDV (245 kbps) with its throughput of 295 kbps. Conclusion: The proposed procedure is more energy efficient than AODV, DSR, and DSDV as it consumes only 0.39 J compared to 0.44, 0.47, and 0.50 J, respectively.

V. CONCLUSION AND FUTURE SCOPE

A novel technique of optimization called Enhanced Monarch Butterfly Optimization (EMBO) was assessed with its resource management ability in MANET. Five benchmark algorithms are taken and compared to analyze performance differences in resource allocation, bandwidth consumption, and energy.

With EMBO, performance regarding specificity, accuracy, F-measure, and sensitivity, in the given data sets is high. Its adaptive convergence factor, dynamic node allocation, and intelligent mutation mechanism were necessary in optimizing resource allocation and network efficiency under changing network conditions.

EMBO, being able to dynamically adapt itself to real-time conditions, allows it to perform better at higher levels, and is therefore a robust solution to such complex and dynamic MANET environments.

Future research should include extension of the evaluation of EMBO to larger-scale and more complex MANET environments, hybrid optimization techniques, integration of EMBO with machine learning, and evaluation of its performance with diverse traffic types. Moreover, energy-efficient versions of EMBO should be focused upon for improving the sustainability of MANETs and real-world implementations to address node failures and network partitioning.

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