Research Project – I (CS4093)

Comparative Study of EVOA for Optimising Resource Allocation in LoRaWAN

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Problem Statement

- Resource allocation in LoRaWAN networks presents significant challenges due to the need to optimise bandwidth, power, and data transmission time to support long-range, low-power communication, especially in dense IoT networks.

- Current resource allocation strategies often struggle to balance low power consumption with reliable data transmission over large distances, leading to issues like suboptimal data rates, excessive interference, and reduced battery life.

- To address these limitations, this study explores the Energy Valley Optimization Algorithm (EVOA), a novel metaheuristic approach, as a solution for optimizing resource allocation in LoRaWAN networks.

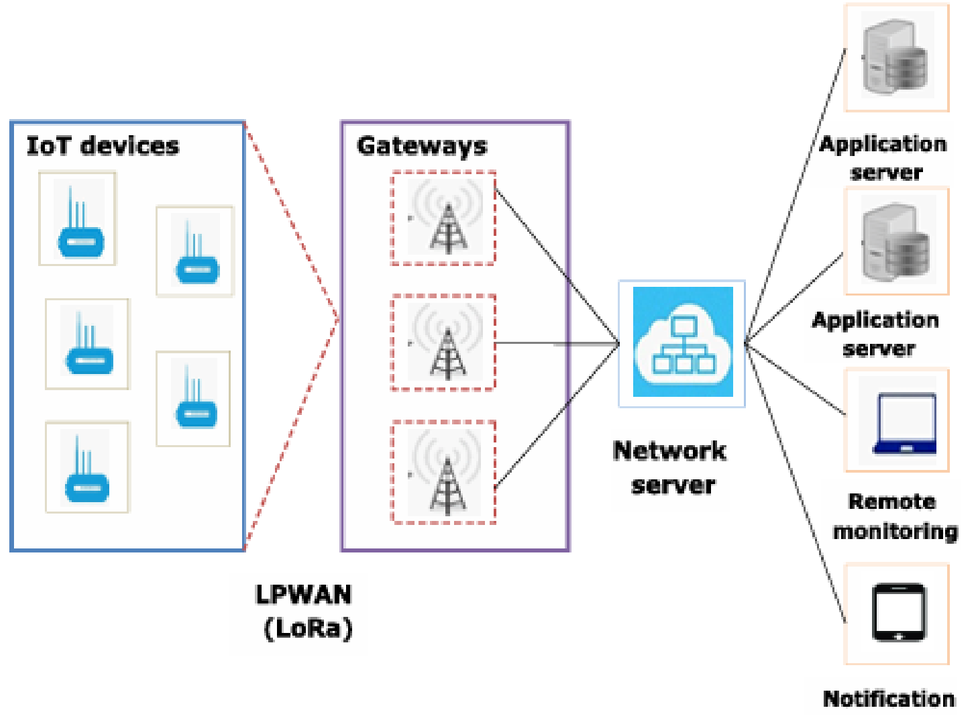
Objective

The primary objective of this research project is to evaluate the **Energy Valley Optimization Algorithm (EVOA)** as a solution for optimising resource allocation in **LoRaWAN** networks, with a focus on enhancing key network performance metrics.

- The study will integrate the EVOA algorithm into a LoRaWAN simulation framework to explore its efficacy in optimising resource allocation.

- Additionally, it will conduct a comparative analysis between EVOA and other prominent optimization techniques, like Genetic Algorithm (GA) and Particle Swarm Optimization (PSO).

- **LoRaWAN** is a low-power protocol suited for long-range IoT communications, yet it faces challenges in optimal resource allocation. Effective control over parameters like transmission power and channel selection is critical to improve network performance. A model of LPWAN is shown to illustrate the network structure



- Among the various LPWAN (Low-Power Wide Area Network) solutions, LoRaWAN has gained prominence for its ability to provide robust, long-range data transmission.

- However, efficient resource allocation in LoRaWAN remains a significant challenge, as current strategies often struggle to balance low power consumption with reliable communication over extended distances.

Why Need for a Better Optimization Algorithm?

- Current resource allocation methods in LoRaWAN, such as rule-based algorithms or standardized heuristics, often fail to adapt dynamically to changes in network load, device density, and environmental factors.

- Several studies have explored diverse research approaches to enhance resource allocation in LoRaWAN networks, focusing on optimising transmission power, energy efficiency, and network performance.

Energy Valley Optimization Algorithm (EVOA)

- EVOA is a physics-inspired metaheuristic optimization technique that models candidate solutions as particles in an energy state, where each particle represents a potential solution for LoRaWAN resource allocation parameters such as spreading factor, transmission power, and channel allocation.

- EVOA's particle stability and energy decay mechanisms, which mimic the behavior of subatomic particles, allow it to **effectively search complex optimization** landscapes.

- This makes EVOA a promising solution to address the limitations of current resource allocation strategies in LoRaWAN, which struggle to adapt to dynamic network conditions.

Steps of the Energy Valley Optimization Algorithm (EVOA)

- **Initialization**: The algorithm begins by initialising a population of particles (candidate solutions) randomly within the defined search space. Each particle's position represents a specific combination of transmission parameters.
- **Fitness Evaluation**: Each particle is evaluated based on a fitness function that assesses how well it meets the optimization criteria, such as minimising energy consumption while maximising throughput.
- **Particle Movement**: Inspired by the decay processes in physics, particles adjust their positions in the search space based on their stability levels.
- **Iteration and Convergence**: The process continues iteratively, with particles adjusting their positions based on individual performance and collective knowledge from neighbouring particles.
- **Final Selection**: After several iterations, the best-performing particle(s) are selected as the optimal solution(s) for resource allocation in LPWAN.

Methodology

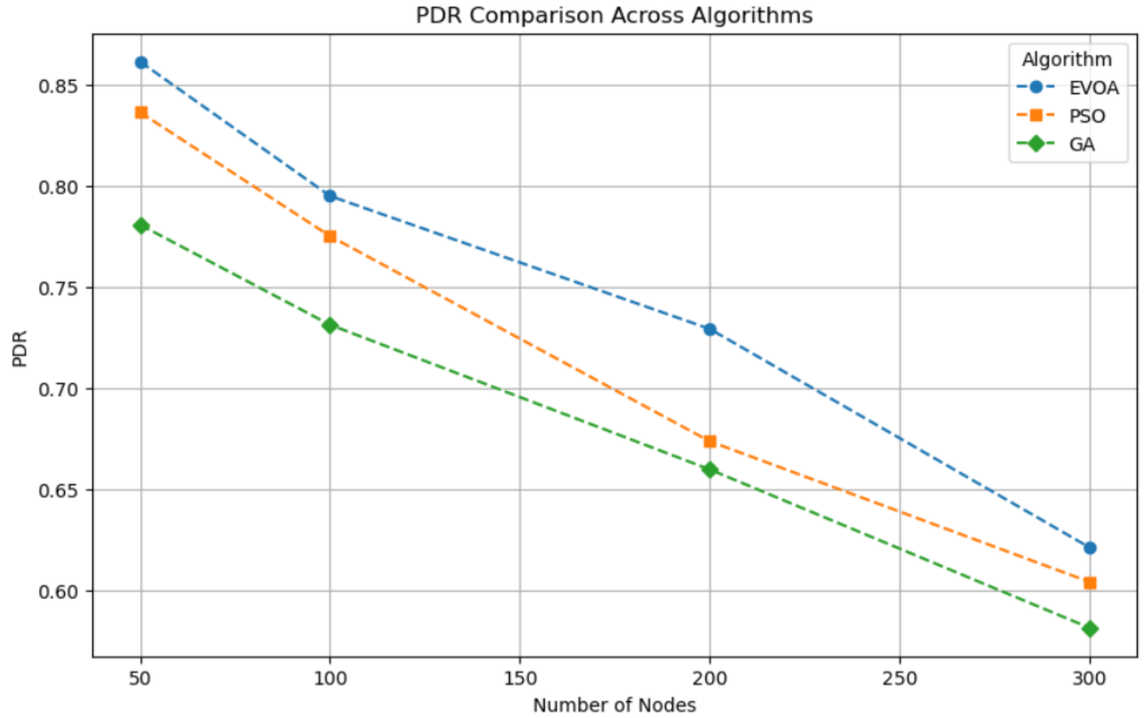
1. **LoRaWAN Setup**
   Python-based SimPy framework used to simulate LoRaWAN components like nodes and gateways.
2. **EVOA Implementation**
   Used Mealpy library for EVOA implementation.
   Optimized parameters: Spreading Factor (SF), Transmission Power (TP), and Channels.
   Fitness function maximizes PDR and minimizes latency, and energy.
3. **PSO Implementation**
   Population-based optimization of SF, bandwidth, and TP.
   Particles update positions based on fitness and global best position.
4. **GA Implementation**
   Simulated natural selection for parameter optimization.
   Iterative evolution using crossover and mutation for optimal configurations.
5. **Performance Evaluation**
   Computed metrics: PDR, energy efficiency, and latency.
   Results consolidated into CSV and visualized using Matplotlib.

Comparative analysis across Algorithms

In this study, we are comparing the results of the EVOA algorithm with the traditional optimisation algorithms namely- Genetic Algorithms (GA), Particle Swarm Optimization (PSO). The results for the metrics are as follows :

✓Packet Delivery Ratio :

EVO shows slightly better results comparatively than the other 2 algorithms for denser networks.



Comparative analysis across Algorithms

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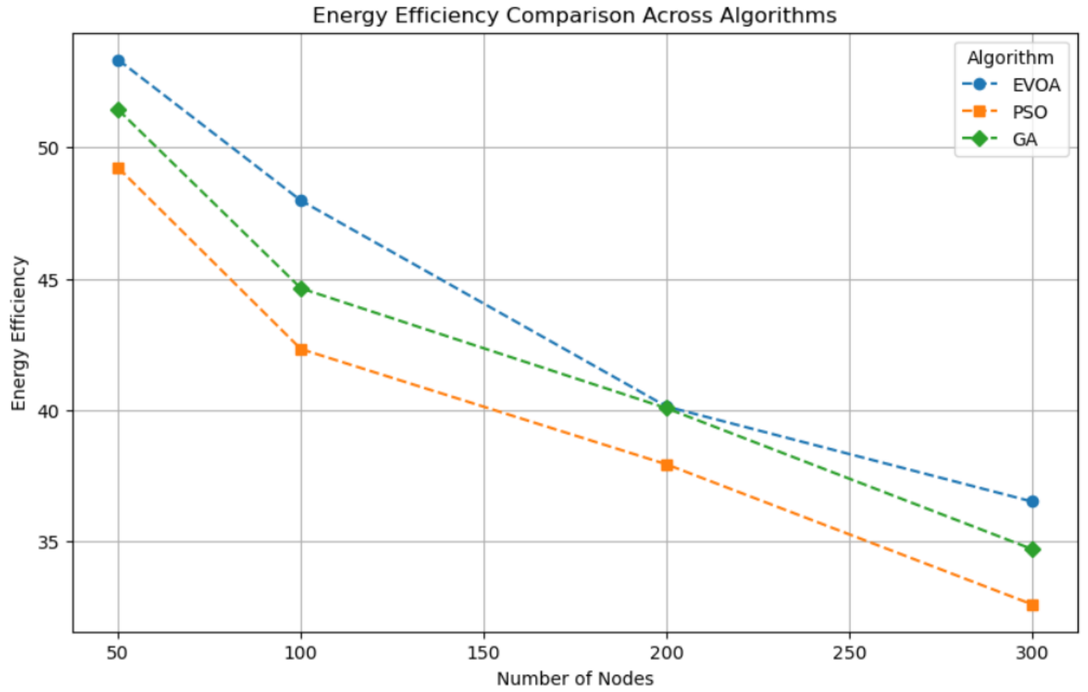
✓**Energy Efficiency:**

As node increases, energy efficiency decreases. EVO tends to show better energy efficiency cooperatively.



Comparative analysis across Algorithms

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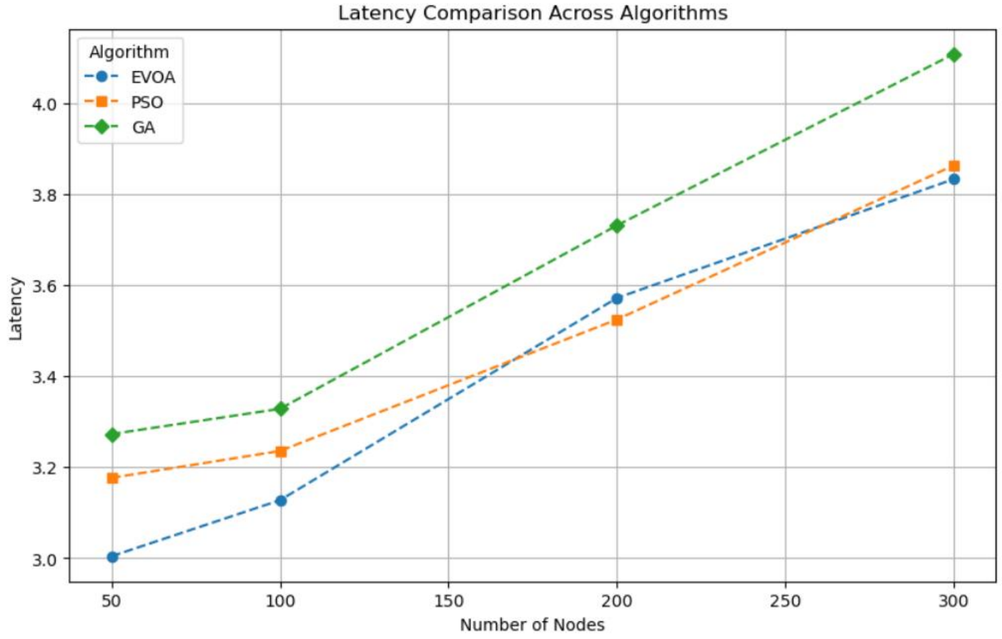
✓**Latency :**

As node increases, latency increases. EVOA tends to show lower latency even though it’s quite similar to PSO for denser networks.



Future Work

The future work for this research project includes

- **Evaluating EVOA's performance in real-world LoRaWAN scenarios.**
  - Implement the EVOA-based resource allocation system in a real-world LoRaWAN deployment to validate its effectiveness in practical settings.
  - Analyze the system's ability to maintain energy efficiency, reduce interference, and enhance data reliability under varying network conditions and device densities.

- **Integrating Machine Learning with EVOA**
  - Use machine learning techniques to analyze node information in the network.
  - Leverage learned insights to enhance resource allocation strategies.
  - Combine machine learning with EVOA to improve performance in dynamic network scenarios.

Conclusion

In conclusion, this research project has examined the potential of the Energy Valley Optimization Algorithm (EVOA) as a solution for optimizing resource allocation in LoRaWAN networks, which is critical for supporting scalable, energy-efficient IoT applications. By analyzing the limitations of traditional resource allocation methods in LoRaWAN, this study identified EVOA, a physics-inspired metaheuristic algorithm, as a promising approach to address the complex optimization challenges.

References

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Thank You