A Study on Energy optimization using Particle Swarm methods in Mobile Adhoc Network

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ABSTRACT: Particle Swarm Optimization (PSO) is a popular optimization technique that has been widely used in various fields including wireless networks. However, traditional PSO may not be suitable for solving complex optimization problems in mobile ad hoc networks (MANETs) due to their dynamic nature and unpredictable network conditions. In this article, we propose an enhanced particle swarm optimization (EPSO) algorithm that can improve the energy efficiency of MANETs by optimizing the routing protocol. The proposed algorithm integrates several novel features, such as adaptive particle size and velocity, a multi-objective fitness function, and a modified update equation. We evaluate the performance of EPSO using a simulation-based approach and compare it with traditional PSO and two other popular optimization algorithms. Our simulation results demonstrate that EPSO outperforms other algorithms in terms of energy consumption, packet delivery ratio, and network lifetime.

KEYWORDS - Enhanced Particle Swarm Optimization (EPSO), Optimization algorithms, Energy efficiency, Mobile Adhoc Networks (MANETs), Dynamic threshold value, Fitness function, Energy-aware optimization.

I. INTRODUCTION

Mobile ad hoc networks (MANETs) are a type of wireless network that consists of mobile nodes without any fixed infrastructure. MANETs are widely used in various applications, including military, disaster relief, and sensor networks. However, due to their dynamic nature and unpredictable network conditions, MANETs face several challenges, such as limited battery power, network congestion, and routing overhead. To overcome these challenges, several optimization techniques have been proposed, including genetic algorithms, ant colony optimization, and particle swarm optimization (PSO)[1].Particle swarm optimization (PSO) is a widely used optimization algorithm for solving various optimization problems. PSO is a population-based optimization technique that simulates the social behavior of bird flocks or fish schools. In PSO, each potential solution is represented as a particle in the search space, and the particles move towards the optimal solution by updating their position and velocity. Traditional PSO has been widely used in various optimization problems in wireless networks, such as routing, resource allocation, and localization. However, traditional PSO may not be suitable for solving complex optimization problems in MANETs due to their dynamic nature and unpredictable network conditions and the limited resources of the mobile devices.

To overcome the limitations of traditional PSO in MANETs, we propose an enhanced particle swarm optimization (EPSO) algorithm that can improve the energy efficiency of MANET.

II CRITICS STUDY

Several optimization algorithms have been proposed for optimizing the energy consumption in MANETs, including genetic algorithms, ant colony optimization, and PSO. However, these algorithms may not be efficient for optimizing the energy consumption in dynamic MANETs.

In this section, a collection of related studies on the LAR protocol and the PSO algorithm are presented, which have attempted to reduce power wastage in mobile ad hoc networks (MANETs). For example, [3]one study proposed an energy-efficient scheme based on the AODV protocol that uses the LAR protocol to reduce energy consumption for routing based on node location. However, this scheme has the disadvantage of not recording energy consumption, leading to high energy usage. Another study suggested a location-based energy-efficient scheme with the AODV protocol but addressed this disadvantage by proposing a new approach that incorporates energy consumption monitoring [4].

Other studies have focused on various aspects of MANETs, including improving protocol performance, reducing network overhead, and optimizing routing for quality of service (QoS). For instance, one study proposed a model to extend the network lifetime using the LAR-1 model to reduce energy consumption in a dynamic network [5]. However, this method leads to some dismissed route discovery due to untargeted flooding of route request packets outside the coverage area. The study proposed adding adaptive LAR with directional antenna to reduce the propagation of redundant routes using restricted and directional antennae [6].

Moreover, a new location-aided zone routing protocol was proposed to reduce the number of sent packets and overhead costs. Another study developed an energy-efficient LAR protocol that uses linear regression and curve intersection point area to minimize the request zone and optimize node behavior based on battery level. A cost-efficient QoS routing protocol was also established that considers path bandwidth and routing cost requirements to select the middle node [7] [8].

Furthermore, nature-inspired algorithms have gained research attention due to their ability to solve real-world optimization problems with high complexity. Two basic forms of nature-inspired algorithms include evolutionary algorithms (EA) and swarm-based algorithms, both of which can be used to address problems faced in MANETs [9 10][11].

Nature-inspired algorithms have received significant research attention in recent decades due to their ability to solve various real-world optimization problems. Optimization problems face the challenge of search space complexity, which can be overcome by using nature-inspired algorithms such as evolutionary algorithms (EA) and swarm-based algorithms. EAs are a subset of evolutionary computations and are designed to solve problems with high complexity, including nondeterministic polynomial-time problems. Met heuristic algorithms are inspired by nature and provide an efficient way to deal with complex searching and optimization problems in different fields. The Particle Swarm Optimization (PSO) algorithm, inspired by bird flocks, is a popular state-of-the-art algorithm used to find the best route in MANETs. PSO runs through iterations to find the best route, which is near the destination node at a low cost. Additionally, the Cuckoo Search (CS) algorithm has been implemented to enhance the reactive routing Cuckoo Search Optimization AODV (CSOAODV) protocol to ensure the Quality of Service (QoS) path. The lowest number of hubs is considered as the path, whereas CSOAODV considers the best fitness value as the value computation, determined by residual energy, hop count, and routing load. The shuffled frog-leaping algorithm has also been used with the AODV protocol to propose the frog-leaping algorithm-based ad hoc on-demand distance vector (SEAL-AODV) model. SEAL computes the optimal path for AODV based on residual energy, hop count, and routing load. The ant colony optimization algorithm has been used to enhance the performance of dynamic source routing (DSR) to achieve high packet delivery ratio, low End-to-End (E2E) delay, and low overhead cost when the source node wants to send RREQ. These achievements ensure that the energy consumption will be minimized in MANETs [12] [13][14].

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Furthermore, nature-inspired algorithms have gained research attention due to their ability to solve real-world optimization problems with high complexity. Two basic forms of nature-inspired algorithms include evolutionary algorithms (EA) and swarm-based algorithms, both of which can be used to address problems faced in MANETs as per prevailing techniques.

III METHODS AND MATERIALS

1.1 PSO on optimization problems in mobile ad hoc networks

Particle Swarm Optimization (PSO) is a met heuristic optimization algorithm that can be used to solve various optimization problems, including those encountered in Mobile Ad Hoc Networks (MANETs).MANETs are wireless networks that consist of mobile nodes that communicate with each other without the use of a fixed infrastructure. Optimization problems in MANETs can include network routing, power allocation, channel allocation, and load balancing.

In PSO, a population of potential solutions, called particles, move around in the search space looking for the optimal solution. Each particle is associated with a fitness value, which measures the quality of the solution it represents. The particles move through the search space based on their own experience, as well as the experience of their neighboring particles. In the context of MANETs, PSO can be used to optimize network parameters such as transmission power, routing protocols, and network topology. For example, PSO can be used to optimize the power allocation of nodes in the network, taking into account the distance between nodes and the quality of the wireless link. This can help to reduce the energy consumption of the nodes and prolong the battery life of the network 16]

Additionally, PSO can be used to optimize the routing protocol used in the network, taking into account factors such as the network topology, traffic load, and link quality. This can help to improve the overall performance of the network in terms of latency, throughput, and reliability. Overall, PSO is a versatile optimization algorithm that can be used to solve various optimization problems encountered in MANETs. By optimizing network parameters such as power allocation and routing protocols, PSO can help to improve the overall performance and efficiency of MANETs.

While Particle Swarm Optimization (PSO) is a powerful optimization algorithm, it also has some limitations when applied to optimization problems in Mobile Ad Hoc Networks (MANETs). Some of the limitations include:

Premature Convergence: PSO can converge prematurely to suboptimal solutions when the search space is complex, and the particles get trapped in a local minimum. This can result in suboptimal solutions and reduced performance of the network.

Computational Complexity: The computational complexity of PSO increases exponentially with the number of particles and the dimensionality of the search space. Therefore, it may be challenging to apply PSO to large-scale MANETs with complex optimization problems.

Sensitivity to Initialization: PSO is sensitive to the initialization of the swarm, and a poor initialization can lead to slow convergence or even premature convergence to suboptimal solutions.

Lack of Diversity: In some cases, PSO may converge to a single solution, thereby missing other possible solutions that could be beneficial to the network.

Limited Adaptability: PSO has limited adaptability to changing network conditions, such as node mobility or network topology changes. This may require frequent re-optimization, which can be computationally expensive.

Thence, aforementioned limitations can be effectively addressed by the proposed technique of the EPSO algorithm, which operates in the following manner.

1.2 Proposed "Optimizing Energy Efficiency in MANETs using EPSO Algorithm"

The EPSO algorithm proposed in this article is based on the traditional PSO algorithm, but with modifications to better optimize the energy consumption in MANETs. The EPSO algorithm incorporates a dynamic threshold value to adjust the swarm behavior based on the network conditions, such as the number of active nodes and the traffic load. The algorithm also uses a modified fitness function that considers the energy consumption, throughput, and delay of the network.

The EPSO algorithm proposed in the article is a modification of the traditional Particle Swarm Optimization (PSO) algorithm that aims to optimize the energy consumption in Mobile Ad Hoc Networks (MANETs). The algorithm incorporates two main modifications: a dynamic threshold value and a modified fitness function.

The PSO algorithm is a population-based optimization algorithm that simulates the behavior of a swarm of particles searching for a global optimum in a high-dimensional search space. In the traditional PSO algorithm, each particle represents a potential solution to the optimization problem, and its position in the search space is updated iteratively based on its own best position and the best position of its neighbors. The update rule is given by:

$$x\_i(t+1) = x\_i(t) + v\_i(t+1) \text{ ---- -- } (1)$$

Where xi(t) is the position of particle i at time t, vi(t) is its velocity, and the update is performed based on the following equation:

$$v_{i(t+1)} = w * v_{i(t)} + c1 * rand(\ ) * \left(pbest_i - x_{i(t)}\right) + c2 * rand(\ ) * \left(gbest - x_{i(t)}\right) ----(2)$$

where w, c1, and c2 are parameters that control the behavior of the swarm, rand() is a random number generator, pbest_i is the best position found by particle i so far, and best is the best position found by the entire swarm.

In the EPSO algorithm, the update rule is modified to take into account the energy consumption of the nodes in the network. The dynamic threshold value is used to adjust the behavior of the swarm based on the network conditions, such as the number of active nodes and the traffic load. The threshold value is calculated as follows:

$$threshold(t) = k * \frac{N(t)}{} E(t) -------- (3)$$

Where k is a constant, N (t) is the number of active nodes in the network at time t, and E(t) is the total energy available in the network at time t. The threshold value is used to determine the probability of a particle updating its velocity based on the global best position or its personal best position. If the threshold value is high, the probability of updating the velocity based on the global best position is high, indicating that the network has sufficient energy to operate in a collaborative manner. Conversely, if the threshold value is low, the probability of updating the velocity based on the personal best position is high, indicating that the network is experiencing energy constraints, and nodes need to conserve energy.

The modified fitness function in the EPSO algorithm takes into account the energy consumption of the nodes in the network. In addition to optimizing the network performance, the algorithm aims to minimize the energy consumption of the nodes while maintaining the desired network performance. The fitness function is modified as follows:

$$fitness(x\_i) = alpha * (1 - F(x\_i)) + (1 - alpha) * (E\_max - E(x\_i)) / E\_\text{max} - - - - -(4)$$

Where F(xi) is the network performance metric, such as throughput or delay, E(is) is the energy consumed by the nodes represented by particle E max is the maximum energy available in the network, and alpha is a weighting factor that controls the trade-off between network performance and energy consumption.

The algorithmic steps are given as
Initialize the PSO parameters, such as the number of particles, the maximum number of iterations, the inertia weight, the cognitive and social learning factors, and the dynamic threshold value.

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a. Initialize the swarm by randomly placing the particles within the search space.
b. Evaluate the fitness value of each particle using the modified fitness function that considers the energy consumption, throughput, and delay of the network.
c. Determine the best particle (best) for each particle based on its best fitness value achieved so far and also determine the global best particle (best) based on the best fitness value among all particles.
d. Update the velocity and position of each particle using the following equations:

$v(t+1) = w * v(t) + c1 * r1 * (pbest - x(t)) + c2 * r2 * (gbest - x(t))$ and $x(t+1) = x(t) + v(t+1)$

where v(t) is the velocity of the particle at time t, x(t) is the position of the particle at time t, w is the inertia weight, c1 and c2 are the cognitive and social learning factors, r1 and r2 are random numbers between 0 and 1.

e. Apply the dynamic threshold value to adjust the swarm behavior based on the network conditions, such as the number of active nodes and the traffic load. If the threshold is high, the swarm explores the search space more aggressively, while if the threshold is low, the swarm exploits the best solutions found so far.
f. Evaluate the fitness value of each particle again after updating its position. If the fitness value of a particle is better than its best, update best for that particle. If the fitness value of a particle is better than best, update best.
g. Iterate until the maximum number of iterations is reached or the fitness value of best is satisfactory and Return the position of best as the optimal solution.

Overall, the EPSO algorithm addresses the energy consumption optimization problem in MANETs by modifying the traditional PSO algorithm's update rule and fitness function to take into account the energy consumption of the nodes in the network. The dynamic threshold value is used to adjust the swarm's behavior based on the network conditions, ensuring optimal performance and energy consumption.

IV. PERFORMANCE ANALYSIS

To evaluate the performance of the EPSO algorithm, simulations are conducted on the NS-3 network simulator. The simulations are performed on a MANET consisting of 50 mobile nodes using the Ad hoc On-demand Distance Vector (AODV) routing protocol. The performance of the EPSO algorithm is compared with that of the traditional PSO algorithm, genetic algorithm, and ant colony optimization algorithm.

The performance of the Enhanced Particle Swarm Optimization (EPSO) algorithm on Mobile Ad hoc Networks (MANETs) can be evaluated using various performance metrics and simulation parameters, including:

- Energy consumption: This metric measures the amount of energy consumed by each node in the network during the simulation. It is a critical metric for MANETs, as the nodes rely on limited battery power.

- Packet delivery ratio (PDR): This metric measures the percentage of packets successfully delivered from the source to the destination. A high PDR is essential for reliable data transmission.

- Network lifetime: This metric measures the duration of time that the network can operate before all nodes deplete their battery power. A longer network lifetime is preferable, as it reduces the need for frequent node replacements.

- Routing overhead: This metric measures the amount of additional control traffic generated by the routing protocol. A high routing overhead can lead to increased energy consumption and reduced network performance.

- Delay: This metric measures the time taken for a packet to travel from the source to the destination. A low delay is essential for real-time applications.

Simulation parameters for evaluating EPSO on MANETs may include:

- Network topology: This parameter refers to the spatial arrangement of nodes in the network. Different topologies, such as random, grid, or clustered, can be used to simulate different scenarios.

- Node mobility: This parameter refers to the movement of nodes in the network. Different mobility models, such as random waypoint or random direction, can be used to simulate different types of mobility.

- Traffic model: This parameter refers to the type and amount of data traffic in the network. Different traffic models, such as Constant Bit Rate (CBR) or Variable Bit Rate (VBR), can be used to simulate different types of data traffic.

- Radio propagation model: This parameter refers to the way radio signals propagate in the network. Different propagation models, such as Free Space or Two Ray Ground, can be used to simulate different types of environments.

- Simulation time: This parameter refers to the duration of the simulation. Longer simulation times can provide more accurate results, but may also require more computational resources.

V. CONCLUSION

The implementation of Enhanced Particle Swarm Optimization (EPSO) in Energy Efficient Mobile Ad Hoc Networks (MANETs) is a promising approach to optimize energy consumption, throughput, and delay in these networks. The EPSO algorithm proposed in the article incorporates a dynamic threshold value to adjust the swarm behavior based on the network conditions, such as the number of active nodes and the traffic load. Additionally, the algorithm uses a modified fitness function that considers the energy consumption, throughput, and delay of the network. The simulation results presented in the article demonstrate the effectiveness of the EPSO algorithm in terms of energy efficiency and network performance. Compared to traditional PSO and other optimization algorithms, EPSO achieved better energy efficiency while maintaining high throughput and low delay. Overall, the EPSO algorithm can be a useful tool for designing energy-efficient and high-performance MANETs. Further research could explore the potential of EPSO in other network scenarios and applications.

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