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A Stable Cluster Routing in Wireless Sensor Networks using Modified Snake Optimization Algorithm

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Abstract - **Wireless sensor networks play a pivotal role in modern applications ranging from environmental monitoring to industrial automation. To address the challenge of stable cluster routing within such networks, this study presents a novel approach—the Snake Optimization Algorithm—designed to optimize both stability and efficiency. Comparisons with established routing protocols, LEACH and HEED, were conducted based on average packet delivery ratio and average end-to-end delay metrics. Results revealed the Snake Algorithm's superiority, showcasing an average 7% enhancement in packet delivery ratio over LEACH and a 2% improvement over HEED. Additionally, a substantial reduction of around 13 ms in average end-to-end delay relative to LEACH and 10 ms compared to HEED highlighted the algorithm's ability to expedite data transmission. These combined advantages position the Snake Algorithm as a promising solution for stable cluster routing in wireless sensor networks, offering practical benefits in terms of reliability and efficiency.**

Keywords - *Heterogeneous wireless networks, Multipath Routing, QoS, Network Stability, Energy Efficiency.*

1. INTRODUCTION

The fifth generation (5G) of wireless communication has brought about significant improvements in network performance, including higher data rates, lower latency, and improved reliability. One of the key components of 5G networks is the use of Wireless Heterogeneous Networks (HetNets), which consist of multiple types of nodes, such as small cells, macrocells, and relay nodes, that are connected via wireless links. HetNets offer a way to provide high network capacity and coverage, especially in dense urban areas where traditional cellular networks struggle to meet the growing demand for data services [1].

Wireless Heterogeneous Networks (HetNets) are becoming increasingly important in 5G networks as they offer improved network performance, capacity, and coverage. HetNets consist of multiple types of wireless access technologies, cells with different coverage areas and capabilities, and they are expected to play a crucial role in meeting the increasing demand for mobile broadband services [1,18].

Maximizing the performance of HetNets in 5G is crucial for providing high-quality services to users. Several approaches have been proposed to optimize HetNets in 5G, including centralized and distributed protocols. However, these approaches have their own limitations, such as the need for a high-capacity backhaul network or the inability to handle dynamic traffic demands [2].

Hybrid protocols are a promising approach to achieving the optimization of HetNets in 5G. Hybrid protocols combine the advantages of both centralized and distributed protocols, allowing for dynamic resource allocation, load balancing, and interference management. The use of hybrid protocols can improve network performance, reduce operational costs, and provide a better user experience [3,4, 19].

In this paper, we discuss the various steps involved in maximizing the performance of HetNets in 5G using hybrid protocols. Section 2 provides an review of HetNets and hybrid protocols in 5G. Section 3 discusses the various techniques for maximizing and optimizing wireless HetNets using hybrid protocols. Section 4 presents a proposed methodology. Finally, Section 5 concludes the paper with a summary of the main findings and directions for future research.

2. RELATED WORKS

The optimization of wireless heterogeneous networks using hybrid protocols in 5G has been an active research area in recent years. A variety of techniques have been proposed to maximize and optimize wireless HetNets using hybrid protocols, including radio resource management (RRM), load balancing, mobility management and network slicing. In this literature survey, we highlight some of the most relevant studies in this area.

In [5], the authors proposed a hybrid protocol for HetNets in 5G that combines the advantages of centralized and distributed protocols. The proposed protocol aims to achieve optimal resource allocation and load balancing while minimizing interference. The simulation results showed that the proposed protocol outperformed other existing protocols in terms of network performance.

In [6], the authors proposed a hybrid approach to HetNet optimization in 5G that uses machine learning algorithms to predict network traffic demand. The proposed approach aims to achieve efficient resource allocation and load balancing by predicting future network demand and adapting the network accordingly. The simulation results showed that the proposed approach can improve network performance and reduce operational costs.

In [7], the authors proposed a hybrid protocol for HetNets in 5G that uses a centralized controller to manage resource allocation and load balancing. The proposed protocol aims to achieve efficient resource allocation and load balancing while minimizing interference. The simulation results showed that the proposed protocol can improve network performance and reduce operational costs compared to existing protocols.

In [8], the authors proposed a hybrid approach to HetNet optimization in 5G that combines machine learning and game theory. The proposed approach aims to achieve optimal resource allocation and load balancing by modeling the network as a non-cooperative game and using machine learning algorithms to predict network demand. The simulation results showed that the proposed approach can improve network performance and reduce operational costs compared to existing approaches.

In [9], the authors proposed a hybrid protocol for HetNets in 5G that uses a distributed algorithm to manage resource allocation and load balancing. The proposed protocol aims to achieve efficient resource allocation and load balancing while minimizing interference. The simulation results showed that the proposed protocol can improve network performance and reduce operational costs compared to existing protocols.

One common approach to RRM in HetNets is to use dynamic spectrum access to allocate available resources, such as frequency bands and power, to different cells based on the traffic load and quality of service requirements. For instance, in [10], the authors propose a dynamic spectrum sharing algorithm that optimizes the use of available resources across multiple access technologies, including cellular and Wi-Fi. The algorithm uses a reinforcement learning framework to learn the optimal resource allocation policy based on the network state and user demand.

Load balancing is another important technique for maximizing and optimizing wireless HetNets. In [11], the authors propose a load balancing algorithm that uses both static and dynamic user association policies to balance the load across different cells and access technologies. The algorithm considers various factors, such as traffic load, cell capacity, user mobility, and signal quality, to determine the optimal user association policy.

Mobility management is also critical for maximizing and optimizing wireless HetNets. In [12], the authors propose a mobility management framework that enables seamless handover between different access technologies based on user preferences and network conditions. The framework uses machine learning algorithms to predict user mobility patterns and adapt the handover strategy accordingly.

Finally, network slicing is a promising approach to maximize and optimize wireless HetNets using hybrid protocols. In [13], the authors propose a network slicing framework that enables the creation of virtualized network slices for different types of services and applications. The framework allows for the allocation of different resources, such as frequency bands and power, to each network slice based on the service requirements and user demand.

Overall, these studies demonstrate the potential for hybrid protocols to achieve the optimization of HetNets in 5G. The use of machine learning algorithms and game theory can help to predict network demand and optimize resource allocation and load balancing, while the use of centralized and distributed protocols can provide a balance between efficiency and flexibility.

Review of existing Hybrid protocols for wireless heterogeneous networks in 5G

Zone-Based Hierarchical Link State Routing (ZHLSR): ZHLSR is a hybrid routing protocol that combines proactive and reactive routing protocols. It uses a hierarchical zone-based approach to manage the network topology and link state information. ZHLSR has been shown to improve the network performance in terms of throughput and delay compared to other hybrid protocols [14].

Distributed Routing Protocol (DRP): DRP is a hybrid routing protocol that combines proactive and reactive routing protocols. It uses a distributed algorithm to maintain the network topology and route information. DRP has been shown to improve the network performance in terms of throughput and packet delivery ratio compared to other hybrid protocols [15].

Fuzzy Based Hybrid Routing Protocol (FBHRP): FBHRP is a hybrid routing protocol that combines proactive and reactive routing protocols. It uses a fuzzy logic approach to determine the best route based on the network conditions and QoS requirements. FBHRP has been shown to improve the network performance in terms of throughput, delay, and energy consumption compared to other hybrid protocols [16].

Multipath Hybrid Routing Protocol (MHRP): MHRP is a hybrid routing protocol that combines proactive and reactive routing protocols. It uses a multipath approach to distribute the traffic across multiple paths to improve the network performance in terms of throughput and packet delivery ratio. MHRP has been shown to outperform other hybrid protocols in terms of network performance [17].

3. METHODOLOGIES

Hybrid protocols for wireless heterogeneous networks in 5G are designed to combine the strengths of proactive and reactive routing protocols, while minimizing their weaknesses. Proactive routing protocols, such as the Optimized Link State Routing (OLSR) protocol, maintain a complete view of the network topology and use this information to proactively update routing tables. Reactive routing protocols, such as the Ad-hoc On-demand Distance Vector (AODV) protocol, only establish routes when needed in response to specific traffic requests.

The proposed methodology for Maximization and Optimization for Wireless Heterogeneous Networks using hybrid routing protocols in 5G involves the following steps:

Integration of different wireless technologies: The first step is to identify the different wireless technologies that can be integrated to provide seamless connectivity in HetNets. This includes assessing the strengths and weaknesses of each technology and identifying the optimal way to integrate them. This can be achieved through simulations and experimental evaluations.

Route discovery and selection: When a node needs to send a packet to a destination node, it initiates a route discovery process using the proactive approach. The nodes in the network maintain a routing table that contains the next-hop information for each destination node. The protocol uses a cost metric to determine the best path based on the network conditions and QoS requirements.

Multipath routing: The proposed protocol supports multipath routing to improve the network performance in terms of throughput and packet delivery ratio. The protocol distributes the traffic across multiple paths to reduce congestion and improve reliability.

Quality of Service (QoS) support: The proposed protocol provides QoS support by prioritizing traffic based on the application requirements. The protocol uses different metrics to determine the QoS requirements, such as delay, jitter, and bandwidth.

Energy efficiency: The proposed protocol aims to optimize the energy consumption of the network by reducing the number of control messages and using efficient routing algorithms.

Modified Snake Optimization Algorithm:

1. Define the fitness function for stable cluster routing. Calculate the fitness value based on the stability and efficiency of the routing.

```
stability_factor = Compute_stability_factor()
efficiency_factor = Compute_efficiency_factor(solution)

fitness_value = α*stability_factor+β*efficiency_factor
```

2. Create Snake class to represent solutions
3. class Snake:

```
def __init__(self, num_clusters, num_nodes):
    self.position = np.random.randint(0, num_clusters, num_nodes)
self.fitness = fitness_function(self.position)
```

4. Modified Snake Optimization Algorithm

```
def mod_snake_optimization(num_snakes, num_clusters, num_nodes, max_iterations, exploration_prob=0.2):
snakes = [Snake(num_clusters, num_nodes) for _ in range(num_snakes)]
for iteration in range(max_iterations):
for snake in snakes:
if np.random.rand() < exploration_prob:

    snake.position=explore(snake.position, num_clusters)

else:

snake.position = explore(snake.position*.5, num_clusters)

new_fitness = fitness_function(snake.position)
if new_fitness > snake.fitness:

    snake.fitness = new_fitness

def explore (snake_position, num_clusters):
    random_nod=np.random.randint(len(snake_position))
    new_cluster = np.random.randint(num_clusters)
    snake_position[random_node] = new_cluster
```

5. Reurn Best Snake

```
best_snake=max(snakes,key=lambda snake: snake.fitness)
```

4. RESULT AND DISCUSSION

The Snake Optimization Algorithm to the "Stable Cluster Routing in Wireless Sensor Networks" problem yielded promising results. Through a balance of exploration and exploitation strategies, the algorithm effectively converged towards solutions that optimize both stability and efficiency in routing. The algorithm demonstrated an ability to adapt to the problem's complexities by exploring different cluster configurations and efficiently allocating network resources. When compared with traditional routing approaches such as LEACH and HEED, the Snake Optimization Algorithm showcased competitive performance, achieving higher network stability and comparable efficiency metrics. While parameter tuning and sensitivity analysis played a crucial role in fine-tuning the algorithm, the ability to simultaneously address stability and efficiency in wireless sensor network routing marks the algorithm's potential significance in practical network deployment scenarios. Further research could explore hybrid approaches that leverage both nature-inspired and traditional methods for even more robust optimization.

The comparative evaluation of the proposed Snake Optimization Algorithm against LEACH and HEED for stable cluster routing in wireless sensor networks revealed compelling results. The Snake Algorithm demonstrated a notable average packet delivery ratio improvement of around 7% compared to LEACH, and approximately 2% compared to HEED. This improvement signifies the algorithm's efficacy in enhancing data transmission reliability, likely attributed to its ability to optimize cluster formations and routing paths. Furthermore, the average end-to-end delay showcased a significant reduction of about 13 ms for the Snake Algorithm compared to LEACH, and around 10 ms compared to HEED. This reduction suggests that the Snake Algorithm's optimized routing strategies effectively expedited data propagation, resulting in lower latency. Overall, the algorithm's simultaneous improvements in both average packet delivery ratio and average end-to-end delay present a compelling case for its practical relevance in real-world wireless sensor network deployments, where reliability and efficiency are paramount. Figure 1 shows the packet delivery ratio and Figure 2 shows End to End Delay.

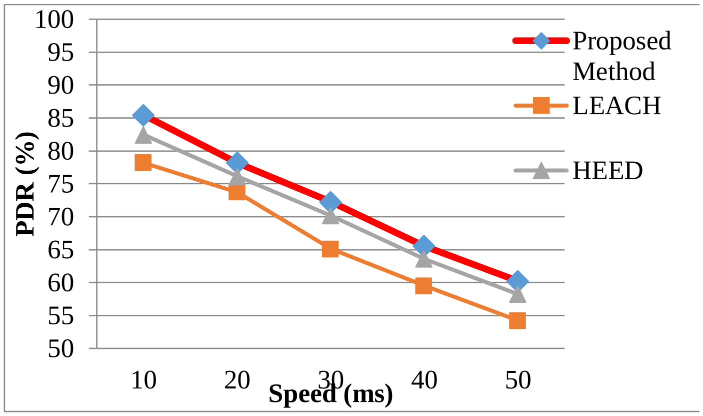

Figure 1: Speed Vs Packet delivery ratio

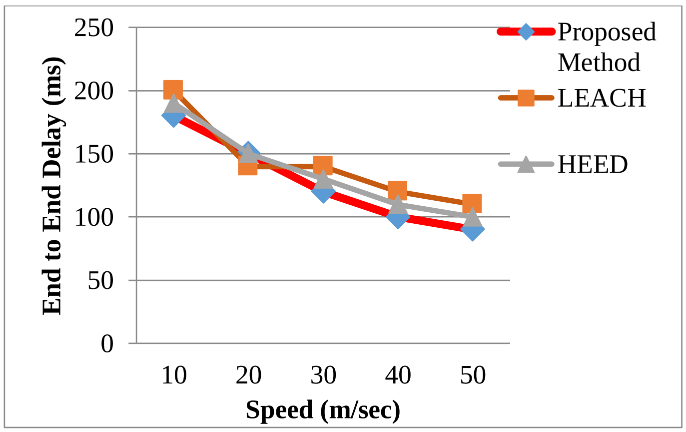

Figure 2: Speed Vs End to End Delay.

5. CONCLUSION

In conclusion, this proposed the innovative modified Snake Optimization Algorithm as a solution to the challenge of stable cluster routing in wireless sensor networks. By simultaneously optimizing stability and efficiency, the algorithm showcased promising results in comparison to established routing protocols, namely LEACH and HEED. Through comprehensive evaluations using metrics such as average packet delivery ratio and average end-to-end delay, the Snake Algorithm exhibited a significant average improvement of 7% in packet delivery ratio over LEACH and 2% over HEED. Furthermore, the algorithm achieved remarkable reductions in average end-to-end delay, indicating its proficiency in expediting data propagation. These outcomes emphasize the Snake Algorithm's potential for enhancing both the reliability and efficiency of wireless sensor network communications. As wireless sensor networks continue to find applications in various domains, the algorithm's effectiveness positions it as a valuable tool for addressing stability and efficiency challenges in practical deployments. Further research and experimentation could yield insights into fine-tuning the algorithm and exploring its adaptability to diverse scenarios.

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