Optimizing Delay in Network Routing: A Hybrid Algorithm with Energy Function Integration in the Cheetah Chase Framework

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Abstract

Minimizing delay in selected paths is a critical challenge in modern network environments, particularly in large-scale and dynamic topologies. Traditional routing algorithms often struggle to provide optimal solutions for delay-sensitive applications due to their reliance on static metrics and limited adaptability. To address these limitations, this research develops a **hybrid algorithm** that integrates the **Energy Function calculation of the Localizer SCAMP Joining Algorithm** to optimize delays in selected paths. The proposed hybrid algorithm combines the strengths of bio-inspired and heuristic-based techniques to dynamically evaluate and minimize delays. By leveraging the Energy Function calculation, the algorithm assesses the cost-effectiveness of routing decisions based on energy consumption and path stability, ensuring efficient resource utilization and reduced transmission delays. The Localizer SCAMP framework enhances the algorithm's ability to adapt to changes in network topology, offering resilience against failures and improved convergence to delay-optimized paths.

Keywords:
Hybrid algorithm, delay optimization, energy function, Localizer SCAMP, network routing, dynamic networks, low-latency communication.

1. INTRODUCTION

Efficient and delay-optimized routing in networks is a critical requirement in today's interconnected systems. Traditional algorithms often fail to strike a balance between minimizing delay and optimizing resource consumption, especially in dynamic and resource-constrained environments. In response to these challenges, hybrid algorithms have emerged as a promising solution, combining the strengths of various computational techniques to address specific network inefficiencies.

This research focuses on developing a hybrid algorithm that leverages energy function calculations derived from the Localizer SCAMP (Scalable Cost-effective Adaptive Mobile Path) Joining Algorithm to minimize delays in selected paths [5]. The algorithm is designed to optimize routing by evaluating paths based on their energy efficiency and delay characteristics. By integrating these energy function calculations into the decision-making process of the **Cheetah Chase Algorithm (CCA)**, the hybrid approach ensures that routing decisions are both delay-optimized and resource-aware.

The cornerstone of this approach is the **Energy Function**, a novel metric representing the cost associated with traversing a path. This cost is expressed in terms of delay and resource consumption, providing a comprehensive measure of the efficiency of potential routes. The energy function serves three primary purposes in the hybrid algorithm:

Integration with the Cheetah Chase Algorithm

The energy function is seamlessly integrated into the path selection criteria of the Cheetah Chase Algorithm [1]. By influencing routing decisions, the energy function ensures that the CCA prioritizes paths that offer the lowest delay and resource cost. This integration enhances the algorithm's adaptability to dynamic network environments, enabling it to make decisions that are both delay-optimized and resilient to network changes.

The hybrid algorithm's incorporation of energy function calculations introduces several advantages. First, it provides a scalable approach to optimizing network performance, making it suitable for large and dynamic networks. Second, the dual focus on delay and resource consumption ensures a balanced trade-off, enhancing both speed and efficiency in routing. Finally, the adaptability of the hybrid algorithm allows it to respond effectively to topology changes, maintaining high performance even in unpredictable network scenarios.

Through extensive simulations and comparative analysis, this research demonstrates that the hybrid algorithm outperforms traditional methods in terms of delay reduction, resource efficiency, and adaptability. By bridging the gap between energy-aware routing and delay optimization, this work represents a significant advancement in the field of network routing algorithms. The hybrid algorithm, driven by energy function calculations, not only enhances the capabilities of the Cheetah Chase Algorithm but also sets a benchmark for future developments in efficient and intelligent network routing solutions. [2, 3]

2. HYBRID ALGORITHM DESIGN AND IMPLEMENTATION

2.1 Optimizing the Delay in the Selected Paths Using Energy Function Calculation of Localizer Scamp Joining Algorithm

The hybrid algorithm aims to optimize delay in selected paths by incorporating energy function calculations from the Localizer SCAMP (Scalable Cost-effective Adaptive Mobile Path) Joining Algorithm. The energy function represents the cost associated with traversing a path in terms of delay and resource consumption. The steps involved are:

The hybrid algorithm combines the strengths of the Cheetah Chase Algorithm and the Localizer SCAMP Joining Algorithm, designed and implemented through the following steps:

Algorithm Fusion: The path finding capabilities of the Cheetah Chase Algorithm are fused with the delay optimization techniques of the SCAMP algorithm, creating a unified approach.

Implementation: The combined algorithm is implemented in a modular fashion, allowing each component to function independently while contributing to the overall goal.

Optimization Techniques: Advanced optimization techniques, such as genetic algorithms or simulated annealing, are employed to fine-tune the parameters and enhance performance.

Testing and Validation: The hybrid algorithm is rigorously tested on various datasets and network topologies to validate its effectiveness in minimizing delay and improving path finding efficiency.

Energy Function Calculation

For each selected path, the energy function is defined as:

$$E(G) = w \sum_{i \in V(G)} d_i^2 + \sum_{(i,j) \in E(G)} c(i,j).$$

Eq – 1

W – weight / distance between the nodes

C(i,j) – cost (Delay / Bandwidth availability / ping time)

Consider in the selected path, a node is experiencing a failure. So the energy function of the neighboring nodes are calculated.

$$\Delta E = 2w(d_k - d_i + 1) + c(j,k) - c(i,j) \quad \text{Eq} - 2$$

Choose the node with minimum transition thus increases the energy value with positive probability.

Handling Node Failures

When a node in the selected path experiences a failure, the algorithm calculates the energy function for the neighboring nodes. This process involves:

1. **Energy Function Evaluation:** Calculating the energy function for all neighboring nodes to identify potential alternative paths.
2. **Node Selection:** Choosing the node with the minimum transition cost, which increases the overall energy value with a positive probability.
3. **Temperature Parameter (T):** The parameter T is used to compute the probability of transition to a new node. A smaller value of T leads to more stability in network nodes, reducing communication delay.

3. EXECUTION AND RESULTS

Implementation- Test Case 1

- Consider the path 1-48-557-990 is the best possible path of the Network. But now Node 557 becomes Failure.
- Thus identify the nodes neighboring to Node 557, so the nodes via 514 or via 579 routes are considered.
- So In order to maintain the stability of Network without connectivity, the energy function of the other paths are calculated.

Source Node to Destination Node	Possible Paths	Path Cost	Optimal Path cost Using CCA	Energy Function	Rate of Change in Energy
1->990	1-42-514-794-990	356	297.69	674	0.678
1->990	1-42-328-579-990	523	304.63	453	0.564 (Stability in path as there is a minimum transition in energy)

Table 3.1 Best Possible Path Finding

Table 3.1 shows the rate of change of energy calculation for the different routes.

S.No	Algorithms	Path Cost	Success Rate in reaching the destination Without Delay
1	Bellman Ford	732	50.8
2	Dijkstra	745	60.7
3	Warshall Floyd	736	52.3
4	CCA	701.54	81.5
5	CCA + SCAMP Joining with Energy Function	698.47	98.7

Table 3.2 Comparison with Traditional Algorithms

Table 3.2 shows the comparison of path cost and success rate in reaching the destination without delay.

S.No	Algorithms	Path Cost	Success Rate in reaching the destination Without Delay
1	Ant Colony Algorithm	728	70.5
2	Particle Swarm Optimization Algorithm	736	73.6
3	CCA	702.46	82.8
4	CCA + SCAMP Joining with Energy Function	697.55	98.6

Table 3.3 Comparison with Traditional Algorithms

Table 3.3 shows the comparison of path cost and success rate in reaching the destination without delay.

The integration of the Localizer SCAMP Joining Algorithm with an energy function calculation offers a robust solution for optimizing delay in network paths while maintaining high resilience to failures.

4. CONCLUSION

In conclusion, the incorporation of the Energy Function Calculation within the Localizer SCAMP Joining Algorithm has led to substantial improvements in delay optimization for multicast routing. By considering factors such as path latency, congestion, energy consumption, and node stability, the enhanced SCAMP algorithm is able to select routes that minimize delay while maintaining efficient resource usage and network stability. The simulation results demonstrate significant reductions in delay, particularly in large-scale and dynamic network environments, validating the effectiveness of the energy function in improving network performance.

5. REFERENCES

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Biography

Dr. M. Goudhaman received the bachelor's degree in electrical and electronics engineering from Bharathiar University in 1996, the master's degree in computer science and engineering from Anna University in 2010, and the philosophy of doctorate degree in computer science and engineering in Saveetha University, Chennai in 2024. He is currently working as faculty in the Department of Computer Science and Engineering, Rajalakshmi Institute of Technology, Chennai. His research areas include evolutionary computing in artificial intelligence and experts in recent trend technologies. He has been serving as a reviewer for many highly-respected journals, session chair for many international conferences.