Optimizing Routing Efficiency in Dynamic Networks Using the Cheetah Chase Algorithm with Novel Convergence Time and Rate Metrics

M. Goudhaman[1], N. Vanathi[2], Adithya GV[3]*

1Assistant Professor - CSE, RajaIakshmi Institute of Technology, goudhaman@ritchennai.edu.in

2Associate Professor - Mathematics, Vels Institute of Science, Technology & Advanced Studies, vanathi.sbs@vistas.ac.in

3Student- CSE, KCG College of Technology, aadithyagoudhaman@gmail.com.

Abstract

In dynamic network environments, the efficiency of routing algorithms is often determined by their ability to converge quickly and stably to the shortest path. Traditional routing algorithms, such as RIP, OSPF, and BGP, frequently face challenges in achieving consistent convergence, leading to increased latency, routing loops, and suboptimal performance. To address these issues, this research introduces **novel metrics for Convergence Time and Convergence Rate** aimed at achieving minimum path distance while ensuring a stable and reliable convergence process. The proposed methodology integrates these metrics into the design and evaluation of routing algorithms, offering a comprehensive approach to performance enhancement. Through simulations and comparative analysis, the new metrics demonstrate their effectiveness in reducing path costs, improving routing accuracy, and maintaining stability in both static and dynamic network scenarios.

Keywords:
Convergence time, convergence rate, network routing, stability, shortest path, performance metrics, dynamic networks.

1. INTRODUCTION

The increasing complexity of dynamic network environments necessitates the development of advanced routing algorithms capable of delivering both efficiency and reliability. Traditional algorithms such as RIP (Routing Information Protocol), OSPF (Open Shortest Path First), and BGP (Border Gateway Protocol) often fall short in achieving consistent and rapid convergence to the shortest path. These limitations are especially pronounced in scenarios involving frequent topology changes, link failures, or high levels of network traffic. Issues such as increased latency, routing loops, and suboptimal path selection hinder the overall performance and adaptability of these algorithms.

To address these challenges, this work proposes a novel approach incorporating bio-inspired strategies into network routing. At the heart of this research is the **Cheetah Chase Algorithm (CCA)**, designed to emulate the hunting strategies of a cheetah [1, 4]. By leveraging the predator's adaptive techniques, the algorithm aims to optimize path selection and enhance routing performance. A key innovation in this study lies in the introduction of two novel metrics—**Convergence Time** and **Convergence Rate**—to evaluate and refine the algorithm's effectiveness.

The **Convergence Time** metric focuses on quantifying the duration required for the algorithm to identify the shortest path within a dynamic network. This metric emphasizes minimizing delays caused by topology changes or link disruptions, ensuring rapid adaptation to fluctuating network conditions. Complementing this, the **Convergence Rate** metric evaluates the stability and consistency of the algorithm's decision-making process. By maintaining a steady rate of convergence, this metric ensures that routing decisions are not only efficient but also reliable, minimizing oscillations and errors during path selection.

Integrating these metrics into the design and evaluation of the Cheetah Chase Algorithm establishes a robust framework for balancing speed and stability in routing. Through extensive simulations and comparative analysis, the proposed methodology demonstrates significant improvements in path cost reduction, routing accuracy, and adaptability in both static and dynamic network scenarios.

2. DEVELOPMENT OF NOVEL CONVERGENCE METRICS

Definition and Calculation of Convergence Time and Rate

Novel convergence metrics are developed to evaluate the performance of the Cheetah Chase Algorithm. Convergence time is defined as the total time taken by the algorithm to reach the optimal path. Convergence rate is the rate at which the algorithm approaches the optimal path over successive iterations.

Convergence Rate Calculation:

To assess the convergence behaviour of the algorithm, we calculate the convergence rate at each iteration of the optimization process. The convergence rate is defined as the absolute difference between the cost of the current route ($Cost_i$) and the cost of the previous route ($Cost_{i-1}$). Mathematically, the convergence rate at the i-th iteration is given by the formula:

Convergence $Rate_i = Cost_i - Cost_{i-1}$

2.1 NOVEL CONVERGENCE TIME & RATE CALCULATION

In this section, we introduce a novel approach to assess the convergence time and rate of a network after a change occurs, such as a link failure or topology update. Our methodology focuses on analysing various factors that contribute to the overall convergence process, including update interval, detection time, propagation time, and processing time.

Convergence Time:

Convergence time refers to the total time it takes for the network to stabilize after a change occurs. The convergence time is influenced by several key factors:

a. Update Interval (Ui):

The update interval represents the time between consecutive updates sent by a routing protocol.

b. Detection Time (Td):

Detection time refers to the time it takes for a router to detect a network change, such as a link failure or topology change.

c. Propagation Time (Tpp):

Propagation time is the duration it takes for information about a network change to propagate to all routers in the network.

d. Processing Time (Tpr):

Processing time represents the time required for a router to process received updates, recalculate routes, and update its routing and forwarding tables. Efficient processing is essential for minimizing convergence delays.

Convergence Rate:

Convergence rate measures the speed at which the network adapts to changes during the stabilization process. It reflects how quickly routers converge to a consistent and updated routing configuration following a network change. The convergence rate is influenced by factors such as the magnitude of the change, the efficiency of the routing protocol, and the responsiveness of individual routers.

3. EXECUTION AND RESULTS

Definition and Design of Novel Convergence Metrics

The development of novel convergence metrics for the Cheetah Chase Algorithm was driven by the need to ensure faster and more reliable convergence, particularly in large-scale and highly dynamic networks.

Table 3.1 shows the execution results for various nodes with novel convergence calculation of CCA run.

At Time T

Node	Ui	*Td*	*Tpp*	*Tpr*	*Tc*	Convergence rate
1	9	87	32	35	163	0.613
2	7	23	45	36	111	0.901
3	**3**	**21**	**25**	**23**	**72**	**1.388**
4	12	25	30	37	104	0.961
990	**6**	**30**	**29**	**31**	**96**	**1.042**

When Network Changes

Node	Ui	*Td*	*Tpp*	*Tpr*	*Tc*	Convergence rate
1	10	52	41	38	141	0.709
2	12	35	42	40	129	0.775
3	**5**	**32**	**30**	**25**	**92**	**1.087**
4	14	41	35	40	130	0.769
990	**8**	**34**	**34**	**35**	**111**	**0.901**

Table 3.1 Sample path costs using CCA

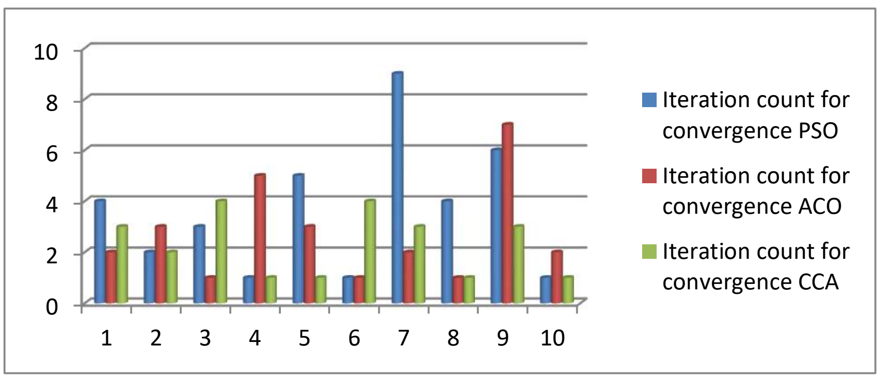

Figure 3.1 Iteration Count for Convergence

Figure 3.1 shows the execution graph for various nodes with novel convergence calculation of other bio inspired algorithms comparison with CCA with respect to iteration count.

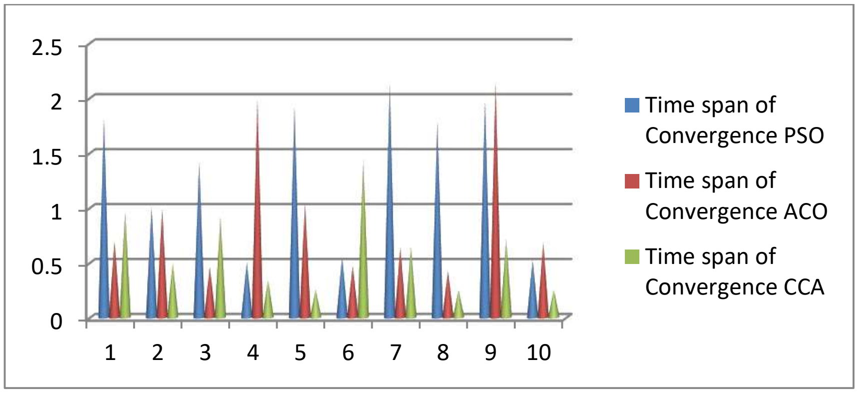

Figure 3.2 Time Span of Convergence

Figure 3.2 shows the execution graph for various nodes with novel convergence calculation of other bio inspired algorithms comparison with CCA with respect to convergence time span.

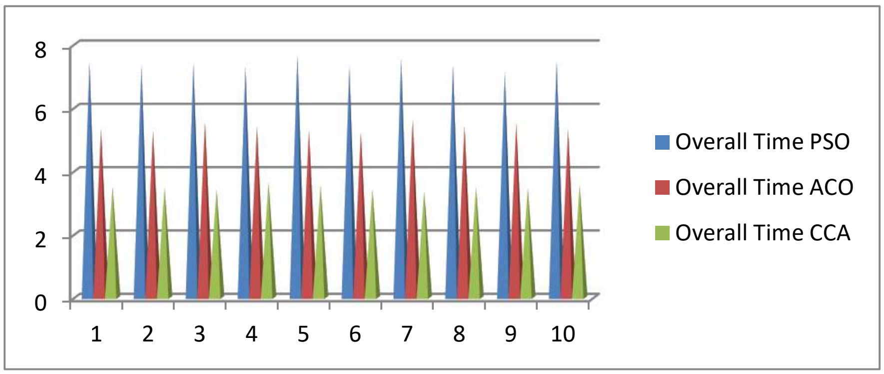

Fig 3.3 Overall Time of Convergence

Figure 3.3 shows the execution graph for various nodes with novel convergence calculation of other bio inspired algorithms comparison with CCA with respect to overall convergence time.

In summary, this module focuses on evaluating the convergence rate of the algorithm to achieve minimum distance with stable convergence in the shortest path optimization process. Through the analysis of convergence rates, we aim to ensure that the algorithm reliably converges to the optimal solution, providing robust and efficient performance in various optimization tasks.

4. CONCLUSION

In conclusion, the development of novel convergence metrics for the Cheetah Chase Algorithm has resulted in significant advancements in network routing performance. [2,3]These metrics have addressed key challenges associated with traditional algorithms, including slow convergence, high overhead, and unstable routing. By incorporating metrics such as proactive acceleration, energy-constrained convergence, latency-awareness, and route reliability, CCA offers a more efficient, reliable, and scalable solution for modern network environments. These enhancements lay the foundation for further research and development, ensuring that the CCA can continue to evolve as a robust routing algorithm for future network architectures.

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.