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Resource Allocation Optimization In 5G Communication Network Using Bacterial Foraging Optimization Algorithm

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Abstract-
In wireless communication networks, resource allocation is a severe challenge because of trade-off between bandwidth efficiency, network performance, and power consumption. This research is employing a Bio-inspired algorithm namely BFO (Bacterial Foraging Optimization), using MATLAB, for improving the resource allocation optimization among multiple users in a 5G wireless network system. The two key network resources which are considered in this optimization problem are and Bandwidth and Power. The fitness function that is considered for this optimization is based on three parameters viz. latency, throughput and reliability. A population of bacteria is simulated by the proposed algorithm which explores the resource space thoroughly following three steps viz. chemotaxis, reproduction, and elimination- dispersal. A possible resource allocation solution is represented by each bacterium which evolves over several iterations for improving the performance. The fitness function has been developed in such a way that its value improves by minimizing latency and maximizing throughput and reliability. In this optimization problem 5 users have been considered with an independent bacteria population for each. Simulation results display efficacy of BFO to provide optimal solutions within minimal iterations. Findings guide that the BFO is providing an adaptive and robust method for wireless resource allocation optimization making it a promising candidate for future intelligent systems pertaining to wireless network management.
Keywords- *5G wireless network; Resource allocation; Bacterial Foraging Optimization; Bandwidth; Power; Fitness function; Latency; Throughput; Reliability; Convergence; MATLAB.*

I.INTRODUCTION

There has been a significant evolution of wireless communication systems over the years for meeting the escalating demand for reliable, efficient and high-speed data transmission. With the arrival of 5G wireless networks, resource allocation has turned out to be a critical aspect in system performance optimization. Bandwidth and Power are two key resources having a direct impact on performance matrices like throughput, latency and reliability. Optimal allocation of these resources is essential for enhancing the QoS (Quality of Service). Several optimization techniques have evolved for addressing this problem. Out of these, swarm-based intelligence methods have gained popularity because of their capability of handling intricate dynamic optimization problems promisingly. One of these techniques is the Bacterial Forging Optimization (BFO) mimicking the behaviour of bacteria looking for optimal solutions within a given search space. This algorithm has displayed a note-worthy performance in finding the optimal solutions of multi objective problems in different domains. The BFO does not need gradient information unlike conventional techniques, and can navigate highly nonlinear spaces efficiently making this algorithm a promising candidate to solve multi objective optimization problems.

Motivation

Traditional optimization methods are not able to cope-up with uncertain and dynamic network conditions properly giving rise to sub optimal performance. Although, machine learning based algorithms are powerful but need a huge training data and computational resources. In contrast to it, heuristic algorithms like BFO provide a balance between solution quality and computational efficiency making them a feasible solution for real time optimization environments.

Research gaps

In the existing studies, it has been observed that various other swarm- intelligence algorithms have been used frequently like Genetic Algorithm, Particle Swarm Optimization etc. but these algorithms often suffer from challenges like premature convergence and complexities in parameter tuning. The BFO overcomes these challenges by maintaining diversity in the pool of solutions and preventing premature convergence. Literature survey has guided that BFO has been used in several other fields like control system, robotics, image processing etc, but it is hardly found explored in addressing resource allocation problem in wireless communication networks. It has been found that some studies are focusing only on optimizing one performance parameter at a time e.g. power efficiency or throughput. However, a trade-off between several conflicting objectives persists in wireless communication networks. Existing resource allocation techniques often fail when number of users is increased resulting in a decline in performance in large-scale networks.

Research objectives

The above research gaps are addressed in the present work implementing resource allocation strategy for 5G wireless network based on BFO (Bacterial Forging Optimization) using MATLAB. The prime objectives of this work are:

1. To develop a fitness function for a 5G wireless network based on three key performance parameters viz. throughput latency and reliability.
2.To implement BFO algorithm in MATLAB to optimize bandwidth and power allocation across multiple users in the considered 5G wireless network.

II. LITERATURE SURVEY

W. Sun et al. proposed a single-stage user-centric wireless resource allocation method for integrated satellite-terrestrial network (ISTN) [1]. Y. Hou et al. proposed JAWC (Joint Allocation of Wireless resource and MEC Computing resource) algorithm for reducing the total delay in network and ensuring the reliability of VUE (Vehicular UE) [2].

Y. Wu et al. proposed a robust resource allocation scheme for secrecy WPCN (wireless powered communication network) [3]. D. Xu and H. Zhu presented energy efficient resource allocation method for wireless powered short packet communication networks [4].

Y. Liu et al. proposed a HMA (Hybrid Multiple Access) scheme which allows MTC (Machine Type Communication) devices to select a suitable multiple access technique based on their channel conditions, QoS requirements, and power constraints [5]. Z. Dong et al. combined the analysis of broadband wireless communication system for optimizing cross-layer wireless communication system's energy efficiency [6].

Y. Liu et al. proposed two importance criteria for differentiating data's importance on basis of their impacts on machine learning [7]. C. Feng et al. introduced the goal-oriented wireless communication resource allocation framework for cyber-physical systems [8].

Y. Xu and G. Gui solved the total rate maximization problem pertaining to a multi-carrier wireless powered BackCom (Backscatter Communication) network [9]. D. Xu and Q. Li focused on cooperative resource allocation in CR (cognitive radio) networks where the PU (primary user) is wirelessly powered [10].

T. P. Do and Y. H. Kim formulated the problems of PA (power allocation) and TA (time allocation), taking residual SI (self-interference) into consideration, for maximizing the sum rate of uplink [11]. K. Lee et al. proposed a low-complexity resource allocation algorithm centered on an optimization method with reduced message passing [12].

H. Zhang et al. investigated the power allocation problem in NOMA (non-orthogonal multiple access)-integrated UAV (unmanned aerial vehicle) communication systems [13].

N. Zhang et al. proposed a new RA (random access) procedure for increasing the number of successful accesses for M2M (machine-to-machine) communication [14].

Lin et al. to methodological difficulties due to 5g spectrum scarcity, [15] introduces dynamic sharing of spectrum at 2.1ghz band as a potential candidate with scheming. They indicate how DSS provides a smooth transition from 4G to 5G through shared spectrum so that coverage and capacity can be further developed. We provide experimental results in diverse spectrum scenarios that serves as a baseline for the future works in the area of spectrum allocation.

Ayepah-Mensah et al. [16] investigate blockchain-embedded federated learning in the context of resource allocation for 5G network slicing. Specifically, they postulate a framework which enables peer-to-peer trading of spectrum to maximize the utilization of spectrum and reduce dependence on centralized controllers. We model the dynamic spectrum management through a Stackelberg game and apply deep reinforcement learning to optimize system utility with respect to latency or revenue.

Chen et al. Investigated the co-existence of ultra-reliable low-latency communication (URLLC) and enhanced mobile broadband (eMBB) in 6G. [17] The first part presents a dynamic spectrum resource allocation model based on a Many-to-Many Matching algorithm and an Advanced K-Granularity Coloring method. The results of the simulation show that an increase in throughput and reduction in latency improve quality of experience (QoE).

Bhattacharya et al. [18] proposed a dynamic spectrum allocation scheme called Deep Blocks based on deep-Q-network (DQN) techniques. Their model provides a more efficient approach than fixed spectrum allocation strategies by incorporating blockchain for secure resource transactions. Proposed method realizes both of servicing latency reduction and spectrum utilization fairness.

Girmay et al. [19] The proposed DSS mechanism in LTE and 5G NR networks does not require the coordination signaling. The proposed model traffic characterization is performed using machine learning, resulting in greater spectrum utilization efficiency and throughput performance in both LTE and NR.

Jokela et al. [20] investigate the use of multimedia alerts based on eMBMS with the LTE/5G networks. They show that combining dynamic spectrum allocation with multimedia warning systems optimizes network traffic and improves the reliability of individual segment messages. Tan et al. In 5G mobile edge computing environments, [21] proposes a quality of experience (QoE)-optimized dynamic adaptive streaming over HTTP (DASH) multicast scheme. Utilizing adaptive grouping and bitrate algorithms during streaming maintains consistent high quality and user experience with low latencies.

Jacob et al. [22] propose a dynamic LSTM model based bidirectional cognitive deep learning framework for spectrum sharing. They apply using CP-OFDMA and they show that CP-OFDMA can provide optimized spectrum utilization for different values of network capabilities. Alqwider et al. [23] propose the IDRAP framework to balance the service requirements of eMBB and URLLC in 5G/6G, and demonstrate that their strategy, based on deep reinforcement learning, outperforms traditional resource management approaches in terms of improving both service satisfaction and network efficiency.

Chen et al. [24] propose an RDRL-based dynamic spectrum access model for reconfigurable wireless networks. The somin5420 spectrum access fairness and throughput enhanced the primary and superior queuing strategy.

III. RESEARCH METHODOLOGY

This research is employing the BFO (Bacterial Foraging Optimization) algorithm, using MATLAB, for optimizing bandwidth and power allocation across multiple users in 5G wireless network. The methodology is an iterative process simulating the natural bacterial behaviour in achieving the optimal resource allocation. The way, the BFO is implemented in this work is presented as a flowchart as shown in the Fig.1. This diagram is illustrating different steps taken by BFO algorithm in addressing considered resource allocation problem. This structured presentation is providing an insight of the work flow of algorithm in finding optimal solution.

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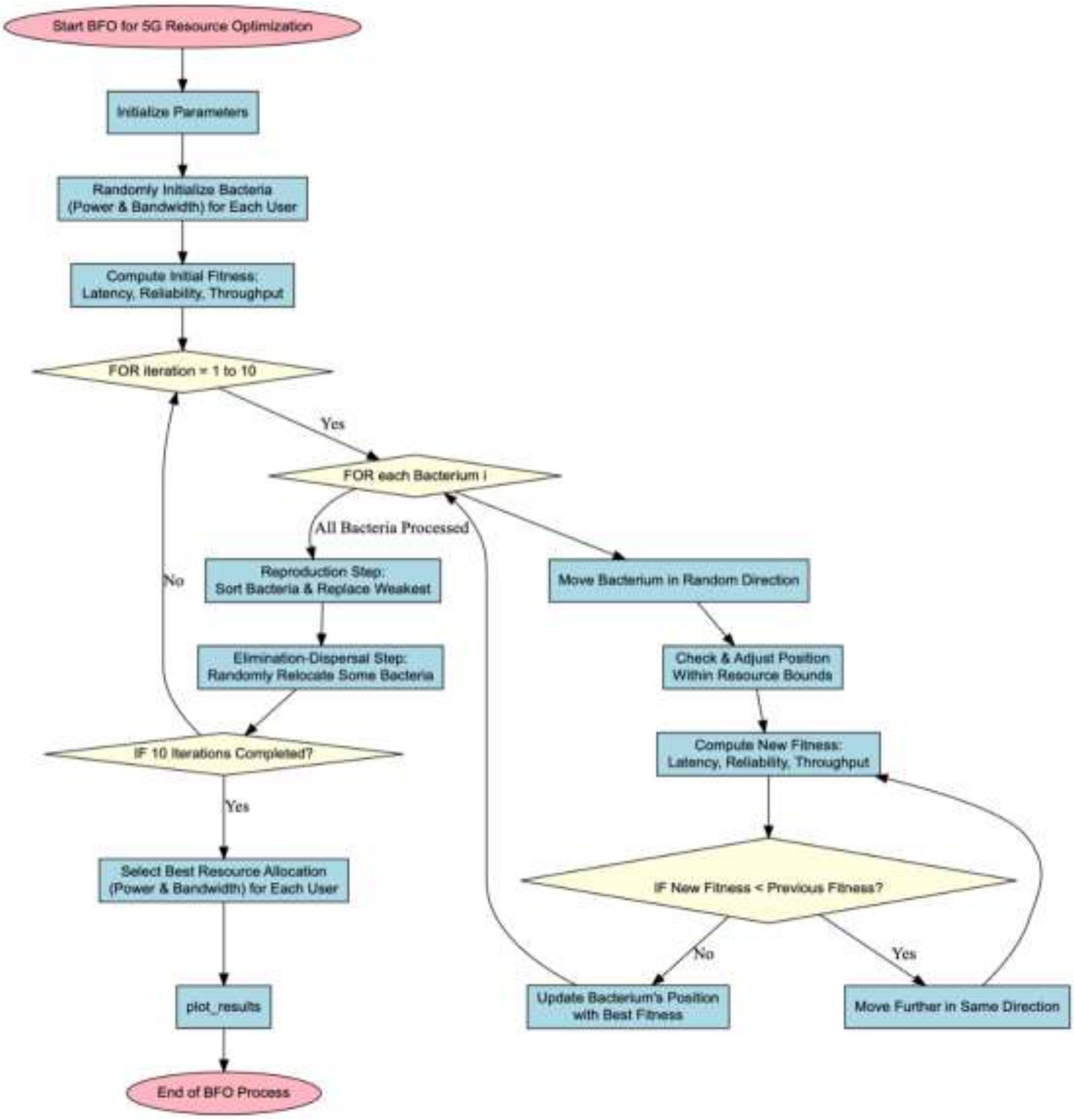

Fig.1 Flow chart of implemented BFO algorithm

Fundamental objective of this work is allocation of bandwidth and power efficiently among 5 users keeping composite cost function (fitness function) at a minimal value. The fitness function includes 3 prime performance matrices viz. Latency, that is inversely proportional to the bandwidth as shown in Fig.2, Throughput that is directly proportional to both bandwidth and power as shown in Fig.3, and Reliability, that exponentially decreases with respect to power consumption as shown in Fig.4.

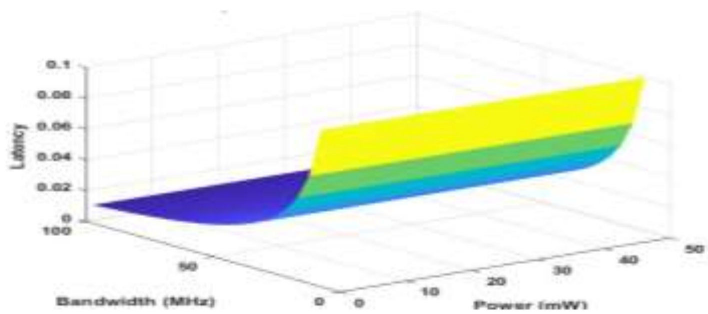

Fig.2 Latency function

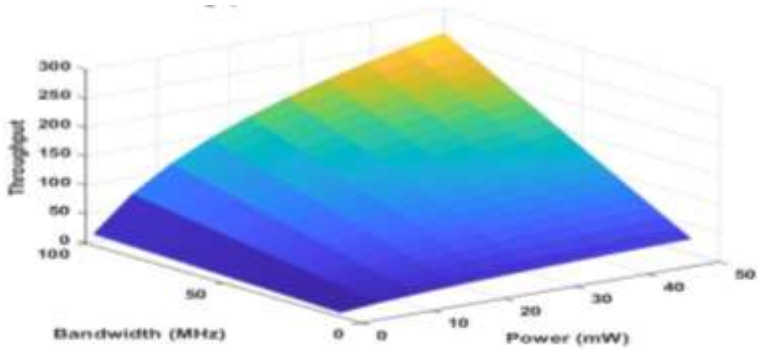

Fig.3 Throughput function

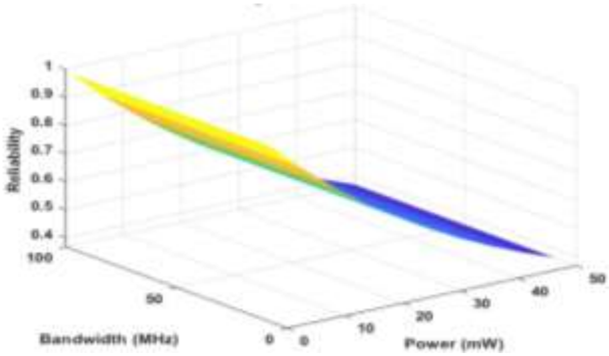

Fig.4 Reliability function

IV. RESULTS AND DISCUSSION

To address the considered optimization problem, the BFO algorithm is implemented in MATLAB with all initializations given in Table I. The convergence behaviour of the algorithm for all users over 10 iterations is shown in Fig.5. A decreasing trend in the values of fitness function with respect to iterations for all users is depicted by this graph. It indicates that there is a gradual improvement in the resource allocation. Convergence of these curves is highlighting the efficacy the BFO in finding near optimal solutions within minimal number of epochs.

TABLE I. INTITIALIZED PARAMETERS

Parameter	Value
No. of users	5
No. of bacteria per user	8
Maximum chemotaxis steps (Iterations)	10
Swim length	2
Elimination dispersal probability	0.3

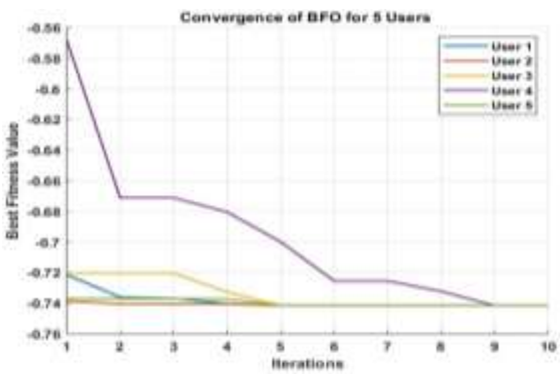

Fig.5 BFO convergence for all users

The result of execution of BFO algorithm is displayed in Fig.6 which is visualizing the finally optimized allocated values of bandwidth and power to considered 5 users. This result verifies that BFO algorithm is distributing the resources efficiently taking into account the constraints on considered performance matrices. The numerical values of allocated power and bandwidth for all five users are presented in Table II showing an optimal allocation balancing throughput, latency and reliability. This table is giving quantitative evidence of efficacy of BFO algorithm in resource allocation optimization.

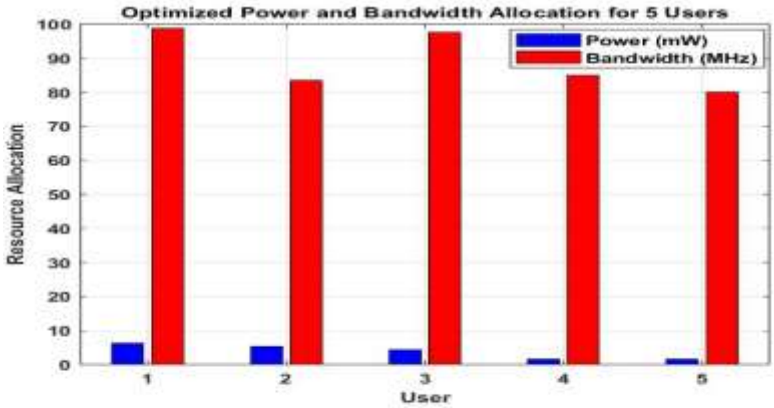

Fig.6 Final resource allocation

TABLE II. OPTIMIZED ALLOCATION OF POWER AND BANDWIDTH

User	Power (mW)	Bandwidth
1	6.22	98.7
2	5.23	83.4
3	4.25	97.5
4	1.50	85.0
5	1.50	80.0

V. **CONCLUSION**

In this research, the BFO (Bacterial Forging Optimization) algorithm has been implemented in MATLAB for addressing the resource allocation problem in 5G wireless communication networks considering three performance parameters viz. throughput, latency and reliability, on the basis of which the fitness function of this problem has been formulated. The prime goal is to allocate two network resources, power and bandwidth to considered users efficiently while minimizing latency and maximizing reliability and throughput. The convergence analysis has verified that BFO is searching the solution space effectively and finding the near optimal solution within minimal number of iterations. It also shows that the fitness function is settling to stable solution in very small number of iterations. This study is demonstrating a practical application of Bacterial Forging Optimization addressing multi objective optimization problem pertaining to 5G wireless networks. Simulation results reveal that BFO algorithm is providing an adaptive and scalable solution which can be implemented in next generation networks wherein the efficient management of bandwidth and power is crucial. The future work could explore scalability of this algorithm in larger networks, and a comparative analysis of BFO with other existing optimization algorithms like Genetic Algorithm, Particle Swarm Optimization, etc. could be performed to find the relative strength and weaknesses associated with BFO algorithm.

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