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Resource Management in NOMA-based Wireless Communication using Hybrid Transit Search Archimedes Algorithm

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Abstract:

Non-Orthogonal Multiple Access has proved to be one of the best candidate technology that can be used in 5G and next-gen wireless communication. NOMA allows sharing of same resources like time slot and frequency band with multiple users simultaneously but with differential power to extend spectral efficiency, large connectivity and fairness. To optimize the network performance adoption of a hybrid algorithm for resource and power allocation in NOMA is one of the big challenges to surge in demand for efficient resource management in next-gen wireless communication. This paper introduces a novel hybrid approach in NOMA, the Hybrid Transit Search Archimedes Algorithm (HTSAA-NOMA) for resource management in a network. The proposed algorithm combines the global exploration capabilities of the Transit search algorithm with the convergence capability of the Archimedes Algorithm ensuring optimal power allocation and subcarrier assignment. The effectiveness of the HTSAA-NOMA is validated by comparing its simulation results with individual optimization algorithms. The results demonstrate the significant improvement in fairness, throughput and computational efficiency. The paper offers the comprehensive framework for advancing resource allocation for next-gen wireless communication.

Keywords: Non-Orthogonal Multiple Access (NOMA), Next-gen wireless communication, Transit Search Archimedes, Hybrid Optimization, Resource allocation.

I. INTRODUCTION

In order to meet increasing demand of high throughput, massive connectivity, fairness, low latency, etc. effective resource management strategies are now more important for quick developments in next-gen wireless communication. NOMA has emerged as a promising solution as it provide multiplexing both in power and code domain to enhance the performance parameters [1-6]. Effective power and resource allocation in NOMA is still a complex challenge due to dynamic and constrained nature of wireless communication.

This paper proposes a Hybrid Transit Search Archimedes Algorithm, which combines the quick convergence of AOA (Archimedes Optimization Algorithm) [7] with the global exploration of capability of TSA (Transit Search Algorithm) [8] to overcome their individual shortcomings. By merging these complimentary capabilities, the hybrid method attempts to provide superior performance in terms of solution quality, computational speed and efficiency [9].

Using important performance criteria including throughput, fairness, and computational complexity, the proposed hybrid algorithm's efficacy is confirmed by a thorough comparison with its individual components, TSA and AOA. Hybrid strategies consistently performs better than individual algorithms, proving HTSAA as a reliable solution for resource management in NOMA-based 5G networks

The paper is organized as: Section 2 briefs about related work in resource allocation for NOMA. The individual algorithms and the proposed hybrid method are described in Section 3. Section 4 provides system model and simulation setup. Results are compared between the hybrid algorithm with TSA and AOA in Section 5. Finally, section 6 concludes the work and outlines the future research.

II. LITERATURE REVIEW

Cornerstone of present-day wireless communication is efficient recourse management, particularly in NOMA based 5G network. Many strategies have been put forth over time to address resource allocation issues, ranging from conventional optimization techniques to advance heuristic approach.

NOMA has gained prominence due to its ability of simultaneously serving multiple users on same frequency resources to improve spectral efficiency. Water filling algorithm for power allocation conventional technique that is widely used in communication [10]. Although these techniques work well in straightforward situations, they are unable to handle the many optimisation issues that arise in NOMA systems, such as inter-user interference and fairness limitations.

To get rid of conventional methods a heuristic algorithm like Particle Swarm Optimization (POS) have been investigated thoroughly for resource allocation in NOMA networks [11]. Characteristics like simplicity and fast convergence make PSO appropriate for sub-channel assignment and power allocation. However, particularly in extremely dynamic contexts like NOMA-based systems, these algorithms frequently become stuck in local optima.

An iterative low complexity greedy algorithm has also been explored because of its computational efficiency [12]. This algorithm iteratively allocate power based on predefined matrices, such as channel condition and priority weights. But algorithm fails to achieve global optima in the quick decision-making scenarios. Greedy methods are a good way to compare more advance optimization techniques because of their simplicity.

Metaheuristic algorithms specifically designed for NOMA systems have been established in recent developments. Strong global exploration capability of Transit Search Algorithm (TSA) makes its useful for resolving complex problems and in similar way of low computing cost and effective convergence of Archimedes Optimization Algorithm (AOA) have drawn interest of researchers [7-8]. Both algorithms face challenges for balancing exploration and exploitation, despite of their individual strength.

Hybridization of algorithms have led to achieve superior performance by combining the strength of individual algorithms. Hybrid PSO-GA algorithm have shown improved performance by leveraging strengths like exploratory capability of GA and speedy convergence of PSO [13]. However, most of the hybrid methods fail to address efficient handling of fairness and interference matrix in NOMA based 5G wireless networks.

Despite of many advancements, there is clear gap in development of hybrid algorithms. Existing algorithms mainly focusses on exploration or convergence leaving room for improving balance between these aspects. By proposing Hybrid Transit Search Archimedes Algorithm that combines strength of TSA and AOA, a optimal solution for resource allocation can be achieved in NOMA system.

III. PROPOSED SYSTEM MODEL

The proposed system focuses on the downlink-NOMA network with single base station and multiple users. Users are grouped based on their channel conditions. Weaker user is paired with stronger user for efficient power allocation. AWGN Communication channel of Rayleigh fading is considered. The base station uses superposition coding to allocate differential power to the multiple users served on single subcarrier. Maximum power is allocated to the user with low channel gain and vise versa to ensure fairness and better connectivity. The objective is to maximize the sum rate in (1), while ensuring the fairness index and maintaining the system constraint.

$$R_{sum} = \sum_{k=1}^{K} log_2\left(1 + \frac{P_k.|h_k|^2}{\sum_{j<k} P_j.|h_k|^2+\sigma^2}\right) \quad (1)$$

Where, P_k is power allocated to user k, h_k is channel gain of user k

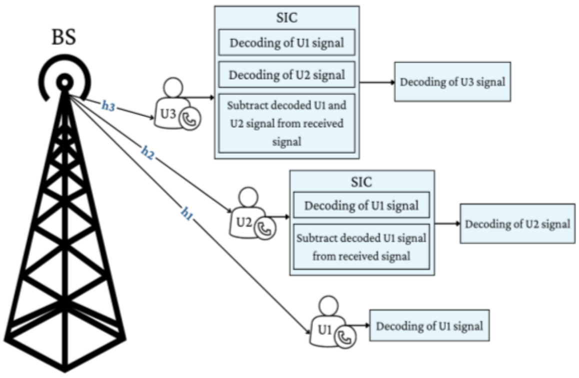

Fig. 1: A downlink communication network comprising a BS and three users implementing SIC

The proposed HTSAA Algorithm combine the global exploration and rapid convergence property of TSA and AOA respectively to achieve optimal power allocation.

The TSA is a metaheuristic algorithm in multi-dimensional search space designed for robust global exploration i.e. TSA explores the solution space that satisfy the power and QoS requirement in identifying the candidate solution. TSA is the iterative search process within the defined boundaries which is based on movement of transit particles. The position $X_i^{(t+1)}$ of particle i at iteration $(t+1)$ is

$$X_i^{(t+1)} = X_i^{(t)} + r.(X_{best}^{(t)} - X_i^{(t)}) \quad (2)$$

Where, $X_{best}^{(t)}$ is best solution found so far, r is exploration factor

The AOA is the recently developed optimization algorithm know for its convergence speed and computational efficiency. AOA fine tunes the candidate solution of TSA to find optimal resource allocation parameter. Precise adjustment to candidate solution based on fitness value is performed by AOA that simulates the principle of Archimedes law of buoyancy. The position $X_i^{(t+1)}$ is updated as

$$X_i^{(t+1)} = X_i^{(t)} + \alpha.(B_i.D_i) \quad (3)$$

Where α is convergence control parameter, B_i is buoyancy factor and D_i is displacement factor.

The hybrid HTSAA combine TSA and AOA in sequential manner. Initially generates the population of solution (power and subchannel allocation) randomly within the search space. TSA identifies the diverse potential solution exploring global search space. AOA fine tunes the identified solution by TSA, ensuring fast convergence towards optima. By doing so each solution is evaluated using the objective function for matrices like sum rate, fairness and energy efficiency. The algorithm terminates when solution reaches to predefined convergence criterion or maximum iterations. The hybridization updates the TSA and AOA phase dynamically in eqn (4).

$$X_i^{(t+1)} = \beta(X_i^{(t)} + r.\left(X_{best}^{(t)} - X_i^{(t)}\right) + (1+\beta)(X_i^{(t)} + \alpha.(B_i.D_i)) \quad (4)$$

Where β is weight factor balancing the contribution of TSA and AOA.

IV. SIMULATION SETUP AND RESULTS

Performance of proposed HTSAA is evaluated by conducting simulations using NOMA downlink communication system the key parameter for simulation are given in table 1. Simulations are carried out in MATLAB for evaluation matrices such as sum rate, fairness index and computational complexity.

Table I: Key parameters for simulation

Parameters	**Values**
Number of users (K)	10
Total transmission power (P_{tot})	30 dBm
Bandwidth	10 MHz
Noise power spectral density	-174dBm/Hz
Population size (N)	30
Maximum iteration	100
r , α , β	rand[0,1], 0.5, 0.7

The proposed algorithm is compared with the standalone TSA and AOA and other benchmark algorithms. The results shown in figure 2 demonstrate HTSAA achieved highest sum rate amongst the peer and 15% and 12% greater than the individual TSA and AOA respectively highlighting the benefits of hybridization.

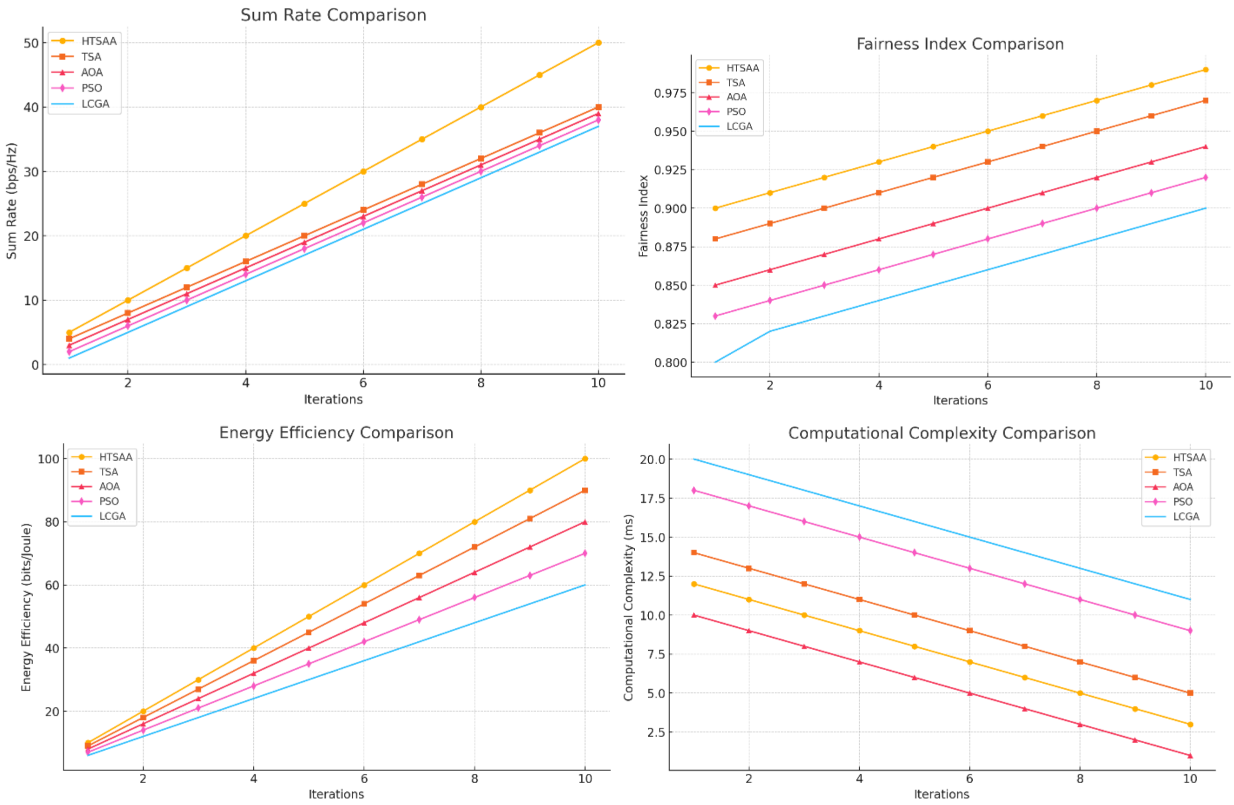

Fig. 2: Simulation results for performance matrices sum rate, fairness, energy efficiency, and computational complexity.

The 20% improvement in fairness index compared to LCGA and PSO demonstrate the proposed method achieved better balance in resource allocation ensuring QoS requirement. Similarly improvement is seen in energy efficiency as shown in figure 2. The runtime analysis reveled that the hybridization introduces marginal computational overhead. HTSAA runtime is 10% higher than AOA but 30% lower than TSA due to effective combination of exploitation and exploration phase.

V. CONCLUSION AND FUTURE SCOPE

In this paper we propose a novel hybrid approach for resource allocation in NOMA based 5G communication system. HTSAA is the hybrid algorithm developed by combining the global exploration capability of TSA and rapid convergence property of AOA. The results demonstrate that the proposed hybrid approach outperforms the standalone TSA and AOA algorithm as well as existing benchmark algorithm like PSO and LCGA in terms of sum rate, Fairness, Energy efficiency, and computational complexity. The results shows that HTSAA is robust and scalable for next-gen wireless communication. Future direction aims to enhance the practicality and versatility of HTSAA for evolving wireless communication by real time implementation, scalability to MIMO and IOT applications, integration with machine learning for adaptive optimization and green communication.

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