IMPROVED QoE IN 5G BASE STATION USING PSO BASED DSA

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Abstract - In the 5G era, base stations can offer multiple services in various scenarios, enhancing spectrum efficiency by utilizing idle frequency bands for low-demand services while ensuring high-priority services are prioritized. This creates a distributed architecture for spectrum allocation. The proposed dynamic spectrum allocation scheme for base stations, optimizes spectrum rearrangement based on service priority, energy consumption, and renting cost. We employ the Particle Swarm Optimization (PSO) algorithm, inspired by bird flocking or fish schooling behavior, to solve the problem. Moreover, provide detailed information on our approach, demonstrating the effectiveness of PSO in optimizing spectrum allocation. By using PSO, we find the optimal solution considering service priority, energy consumption, and renting cost, supported by mathematical proofs of PSO algorithm performance. MATLAB is used as the simulation tool to carry out these techniques. Simulation experiments validate the approach, showing the stability and efficacy of PSO-based algorithm, which aligns with the theoretical analysis.
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Key Words: Spectrum efficiency; 5G; dynamic spectrum allocation; service priority; PSO.

1.INTRODUCTION

The advent of 5G technology holds the potential to completely transform our connectivity, communication, and digital service experiences [1]. With its ultra-high data rates, low latency, and massive connectivity capabilities, 5G has the potential to foster a broad range of applications, including augmented reality, Internet of Things (IoT) devices, virtual reality, autonomous vehicles, and much more. However, to realize the full potential of 5G, it is crucial to ensure an optimal Quality of Experience (QoE) for end-users. QoE refers to the overall satisfaction and performance perceived by users while utilizing various services over the 5G network [2,3].

Efficiently managing radio spectrum resources poses a significant challenge in achieving improved QoE. Spectrum is a limited and valuable resource, and its proper allocation and utilization are critical for maintaining network performance and user satisfaction [6]. Dynamic Spectrum Allocation (DSA) is a promising approach that allows base stations to adaptively manage and allocate spectrum resources in real-time based on the varying demands and network conditions. In this context, utilizing Particle Swarm Optimization (PSO), a nature-inspired optimization algorithm, for DSA in 5G base stations holds great potential to enhance QoE significantly [7].

Dynamic spectrum allocation (DSA) is a technology that allows for the efficient and flexible allocation of radio frequency (RF) spectrum. Traditional spectrum allocation methods involve static assignments of spectrum bands to specific users or applications, which can lead to inefficient use of available spectrum and underutilization of frequency bands. DSA, on the other hand, enables dynamic and adaptive spectrum resource allocation based on real-time demand, enabling more effective use of the spectrum. The process of a 5G base station dynamically allocating frequency bands or spectrum resources to various users or services based on their present demands is known as dynamic spectrum allocation [5].

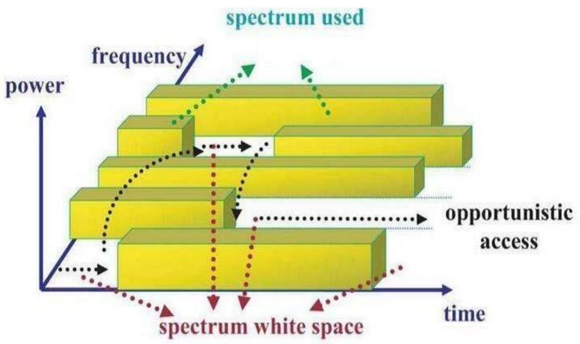


Figure 1: Dynamic Spectrum Allocation

In the Background of 5G base stations, DSA plays a vital role in optimizing network performance and capacity. The base station can dynamically allocate frequency bands to users or services that require them at specific moments, ensuring efficient spectrum utilization and enhancing overall network efficiency.

To further improve the spectrum allocation process, we introduce Particle Swarm Optimization (PSO). PSO is a nature-inspired optimization algorithm that imitates the social behavior of birds flocking or fish schooling. In the pretext of DSA, PSO can be applied to find optimal spectrum allocation solutions by intelligently exploring the search space of possible frequency band assignments [9].

The PSO algorithm consists of a population of particles, each representing a potential solution (frequency band allocation) to the spectrum allocation problem. These particles move through the search space, seeking the best solution by updating their positions based on their own experiences and the experiences of their neighboring particles.

The fitness of each particle's solution is evaluated based on certain criteria, such as interference levels, data rate requirements, and quality of service constraints. The best-performing solutions (particles) guide the others in the swarm, leading to convergence towards an optimal spectrum allocation that maximizes spectrum utilization and minimizes interference.

By combining DSA with PSO, we can create a powerful framework that dynamically and adaptively allocates spectrum resources while optimizing the overall network performance. The synergy between DSA's real-time adaptability and PSO's global search capability results in more efficient and intelligent spectrum allocation decisions .

2. Methodology

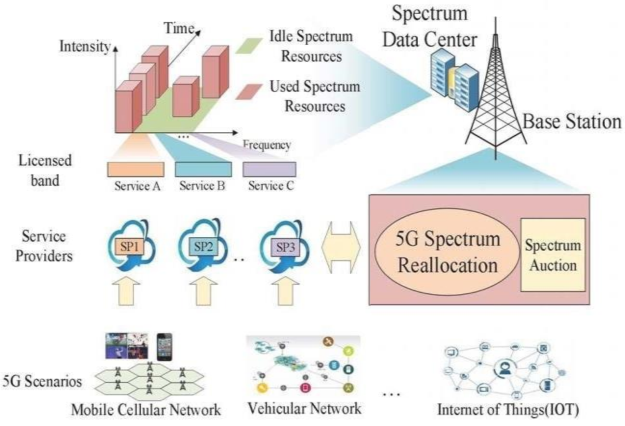


Figure 2: Dynamic Spectrum Management System for 5G Base Stations

Dynamic spectrum allocation by the base station in different scenarios involves optimizing spectrum utilization and meeting the varying demands of services. With each scenario requiring different services and having its own licensed bands, the base station must efficiently allocate spectrum resources. Service requests arrive randomly and differ in terms of bandwidth, latency, and quality of service (QoS) requirements.

To accommodate this, the base station adopts a flexible approach, allowing spectrum rental and temporary usage of idle spectrum among services. By dynamically reallocating spectrum, the base station maximizes utilization and ensures efficient service delivery. This requires continuous monitoring of available spectrum resources through a local spectrum data center. The base station analyzes statistical data from service requests, considering factors such as current utilization, bandwidth requirements, and available spectrum in different scenarios. The base station optimizes the allocation scheme to meet the specific requirements of each scenario.

Lyapunov optimization entails using a Lyapunov function to achieve optimal control of a dynamical system. Lyapunov functions are widely employed to ensure different types of system stability. Lyapunov function serves as a nonnegative scalar indicator of this multi-dimensional state. Its definition is such that it grows large when the system moves toward undesirable states. To achieve system stability, control actions are taken to guide the Lyapunov function's behavior in the negative direction, ultimately approaching zero.

By employing Lyapunov optimization, it becomes possible to design control strategies that steer the system towards desired states while guaranteeing stability.

PSO is a metaheuristic algorithm inspired by the collective behavior of swarming animals searching for food in nature. The concept of PSO was initially proposed by Kenny and Eberhart in 1995.This algorithm mimics the social interactions and dynamic movements observed in birds, fish, and insects. When a swarm of birds disperses in search of food, the one closest to the food source detects it and communicates this information to its nearby companions. This process of information sharing and cooperation enables the swarm to locate the food source effectively.

In PSO, a bird's movement from one location to another represents an optimal solution, and the food they discover symbolizes the global optimum of the entire search. Each individual bird maintains its best-found solution, termed "personal best," while the highest optimal value attained by the entire swarm is known as the "global best." It iteratively optimizes a problem by striving to enhance candidate solutions based on a specified quality measure. In PSO, a swarm comprises a set of particles (NP), with each particle representing a potential solution in the solution space. These particles are characterized by their positions and velocities.

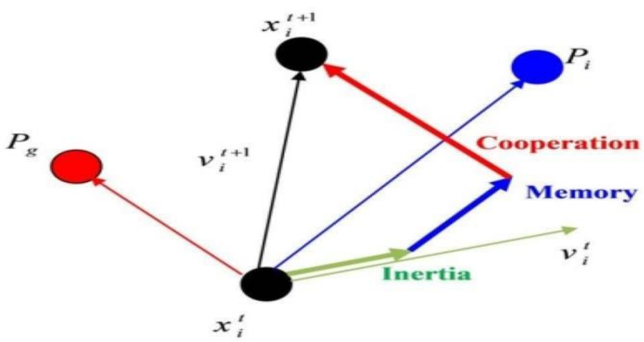


Figure 3: Inside a two-dimensional space the up-gradation of a particle's Position and velocity

Algorithm;

1. Randomly initialize the position and velocity for each particle.
2. Calculate the fitness value of each particle and update their personal best (Pbest) and global best (Gbest) based on the current search.
3. Update the Pbest and Gbest for all secondary users (particles) in the swarm.

4. If the fitness value is better than the current Pbest, update the Pbest.
5. Update the fitness function as the global best.
6. Check if the stopping criteria is reached; if not, go back to step 2.
7. End the algorithm.

Velocity of the particle:

$$V_i^{new} = w * V_i^{old} + a_1 * c_1 * (pbest_i^{old} - P_i^{old}) + a_2 * c_2 * (gbest_i^{old} - P_i^{old})$$

Position of the particle:

$$P_i^{new} = P_i^{old} + V_i^{new}$$

Where:

c1 and c2 are random values
w is the inertia weight
a1 is the accelerating factor of local information
a2 is the accelerating factor of local and global information

FLOW CHART

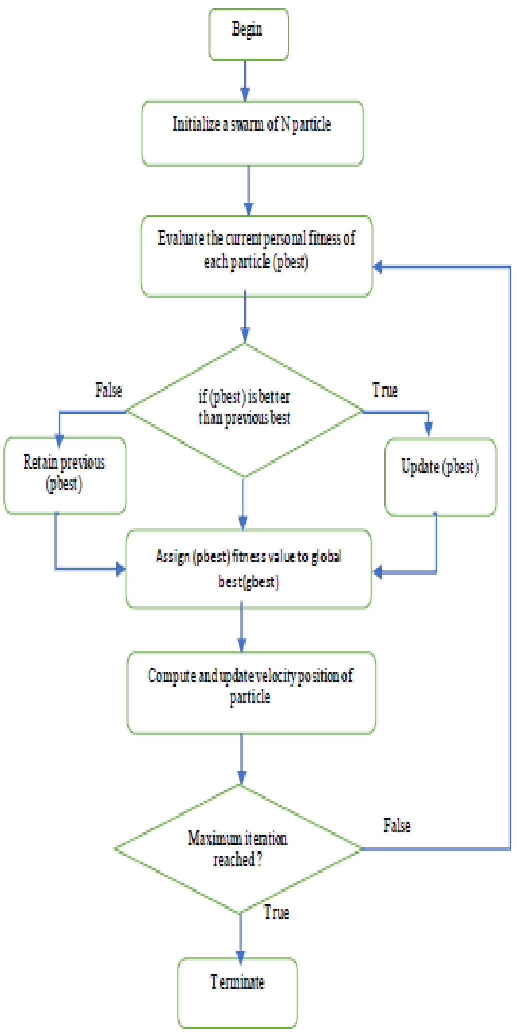


Figure: PSO algorithm

RESULTS:

Parameter	*Value*	*Unit*
a_i	[5*10^7, 3*10^8]	bits
H_i	[-50,-75]	dBm
N_0	-174	dBm/Hz
P_i	43	dBm
c_i	[10,20]	MHz
u_i	1,2,3,4,5	

A. Immediate Penalty and Upper Bound

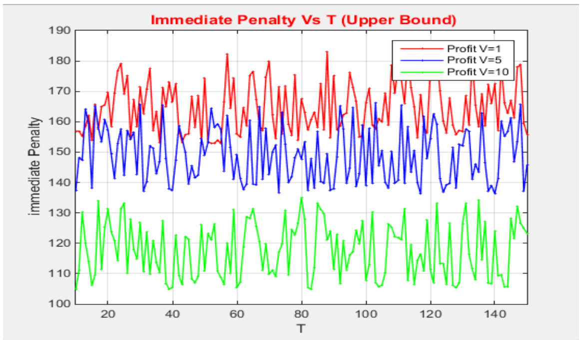


Figure 4: Immediate Penalty Vs Upper Bound

As the profit value increases (V = 1, 5, and 10), the immediate penalty decreases. Conversely, when the profit is lower, the penalty becomes more significant.

B. Queue Backlog

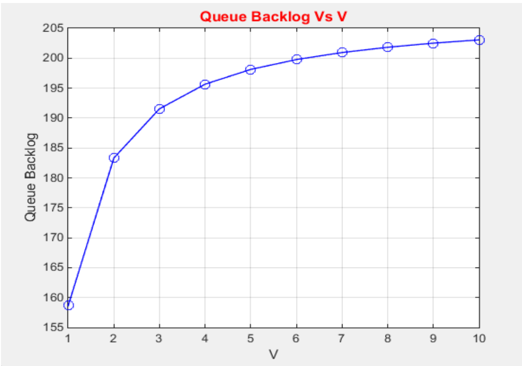


Figure 5: Queue Backlog Vs V

Figure 5 illustrates the correlation between the value of parameter V and the maximum queue backlog. V is a crucial parameter in the DSA method adopted by 5G base stations, as it balances drift and penalty. The graph presents V on the x-axis and the corresponding maximum queue backlog on the y-axis. It showcases a nearly linear relationship, where the maximum backlog increases proportionally with the value of V.

C. Average QoE Decline

$$\eta = \frac{1}{T}\sum_{T}\frac{\sum_{i}\frac{Rate_R^i - Rate_A^i}{Rate_R^i}}{N}$$

Where $Rate^i{}_R$ = requested data rate of service i

$Rate^i{}_A$ = actual data rate of service i

The formula calculates the average decline in Quality of Experience (QoE) over a specified time period (T) when the number of services provided by a 5G base station needs to be reduced. The average QoE decline (η) is computed based on the difference between the requested data rates ($Rate^i$ R) and the actual data rates ($Rate^i$ A) for each service, with the achievable data rates ($Rate^i$ R) for each individual service.

D. Service Heat Rate:

$$\varphi = \frac{1}{T}\sum_{T}\frac{\sum_{i} Rate_R^i}{C_{all}}$$

Where C_{all} = maximum capacity of all spectrum resource

The comparison graph in Figure 6 illustrates the Competence of two distinct spectrum allocation schemes - OLOA and PSO. The x-axis denotes time slots, and the y-axis depicts the average QoE decline of all services. The graph shows that PSO is more efficient in utilizing the available spectrum resources compared to OLOA. Overall, the graph demonstrates that PSO is a more effective spectrum allocation scheme that can improve the QoE of all services in a 5G base station

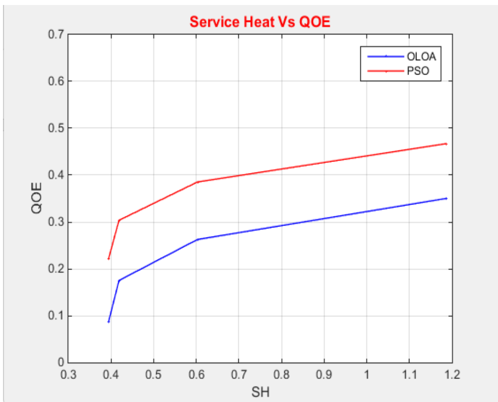


Figure 6: QoE Vs Service Heat Rate

Table -1: OLOA Vs PSO QoE

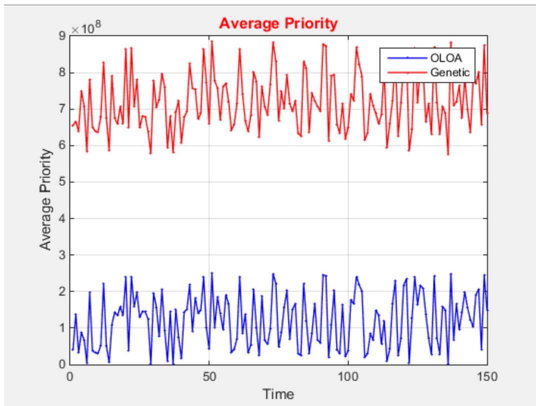
OLOA QoE	**0.087535**	**0.175069**	**0.262604**	**0.350138**
SH	0.3[illegible]	[illegible]	[illegible]	1.185771
PSO QoE	0.2[illegible]	[illegible]	[illegible]77	0.467134

$$pri_A = \frac{\sum_{i} Rate_A^i * u_i}{N}$$

E. Average Priority

Figure 7: Average priority

The time slot is depicted on the x-axis, representing the simulation's unit of time. The average priority of service requests is represented on the y-axis. The graph contains two lines, one for OLOA and one for PSO, illustrating the average



priority's trend over time for each algorithm. From the graph, it is evident that the PSO consistently maintains a higher average priority compared to the OLOA, indicating that PSO excels at prioritizing high-priority requests

3. CONCLUSIONS

The proposed methodology utilizes the Lyapunov optimization method, enabling the simultaneous consideration of various factors, such as service priorities, latency requirements, renting costs, and energy consumption. Through simulations, we obtain persuasive results that illustrate the effectiveness of the spectrum allocation scheme in enhancing 5G spectrum efficiency. This scheme holds significant promise for the future, particularly in scenarios where spectrum reallocation is permitted within the base stations operating under a distributed architecture.

The dynamic spectrum allocation scheme incorporating PSO offers several distinct advantages. One of its key strengths lies in its simplicity of implementation, making it easily accessible for practical deployment in real-world communication systems. Moreover, with relatively few parameters to be tuned, it simplifies the optimization process and reduces the need for exhaustive parameter searches.

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