5G RAN Scheduling Algorithms: A Comparative Simulation Study

Aditya Singhal
B.Tech, CSE, IIIT Vadodara, India
202151008@iiitvadodara.ac.in

Pratyush Dixit
B.Tech, CSE, IIIT Vadodara, India
202151119@iiitvadodara.ac.in

Tarun Manoj Kumar Sahu
B.Tech, CSE, IIIT Vadodara, India
202151171@iiitvadodara.ac.in

Raghav Agiwal
B.Tech, CSE, IIIT Vadodara, India
202151124@iiitvadodara.ac.in

Waikar Om Anant
B.Tech, IT, IIIT Vadodara, India
202152344@iiitvadodara.ac.in

***Abstract*—This report presents a simulation of various scheduling algorithms in 5G Radio Access Networks (RAN). The goal of this study is to compare different scheduling approaches based on bandwidth allocation efficiency and fairness among users with dynamic Quality of Service (QoS) requirements. The following algorithms are evaluated: Round Robin Scheduling, Shortest Job First (SJF), Priority-based Scheduling, Weighted Proportional Fair Scheduling, Earliest Deadline First (EDF), Maximal Scheduling with Interference Mitigation, and Queue-based Scheduling. The performance of each algorithm is compared based on fairness, calculated using variance of allocated bandwidth. Results are presented as textual reports and graphical plots.**

***Index Terms*—5G, RAN Scheduling, Bandwidth Allocation, QoS, Fairness, Simulation.**

I. Introduction

With the rapid advancement of mobile networks, the deployment of 5G technology promises to revolutionize wireless communication by offering significantly faster data speeds, lower latency, and enhanced connectivity. A critical component of 5G networks is the Radio Access Network (RAN), which provides the interface between mobile devices and the core network. Efficient management of limited radio resources, especially bandwidth, is crucial for maintaining a high Quality of Service (QoS) across a wide range of user applications. As demand for mobile data continues to grow, it becomes essential to develop effective scheduling mechanisms that can allocate bandwidth fairly and efficiently to meet diverse user requirements.

In 5G networks, users have varying QoS needs depending on the nature of the services they are accessing. For instance, applications such as real-time video streaming, augmented reality (AR), and virtual reality (VR) require high throughput and low latency, while services such as file downloads or web browsing may tolerate some variability in network performance. The dynamic nature of these demands creates a challenge for bandwidth allocation systems, which must cater to both high-priority and best-effort traffic.

Scheduling algorithms play a pivotal role in determining how bandwidth is distributed across users, ensuring fairness, network efficiency, and the fulfillment of QoS requirements. The goal is to balance between maximizing throughput and minimizing delays while also considering fairness — making sure that no user is unfairly deprived of network resources.

In this paper, we evaluate a set of commonly used scheduling algorithms in the context of 5G RANs. These algorithms are designed to allocate bandwidth in a way that optimizes network performance and fairness. The performance of these algorithms is assessed based on their ability to allocate resources efficiently, maintain fairness, and meet the diverse QoS requirements of users.

We simulate a 5G environment with a dynamic population of users, each having distinct QoS needs and varying bandwidth demands. The simulation results are analyzed and compared across multiple algorithms, providing insights into their strengths, limitations, and suitability for different network conditions.

The rest of the paper is organized as follows: Section II provides a detailed description of the methodology used, including the scheduling algorithms implemented and their respective functions. Section III presents the code and implementation details, including the simulation setup. Section IV discusses the results, providing both graphical and numerical comparisons of the different scheduling algorithms. Finally, Section V concludes the paper by summarizing the findings and suggesting potential directions for future research in the area of bandwidth scheduling in 5G networks. Additionally, Section VI gives an idea of the future scope of continuing.

II. Methodology

The primary objective of this study is to evaluate and compare different scheduling algorithms for bandwidth allocation in 5G Radio Access Networks (RANs). To achieve this, we simulate a network environment with a fixed total bandwidth and a variable number of users, each with unique QoS requirements and requested bandwidth. The performance of each algorithm is evaluated based on its ability to distribute bandwidth efficiently, fairly, and according to user priorities. Below, we describe the various scheduling methods used in this study.

A. User Model

Each user in the simulation is modeled with the following dynamic properties:

- **User ID**: A unique identifier for each user.
- **QoS Type**: A classification indicating the QoS requirement of the user, which can be either *High*, *Medium*, or *Low*.
- **Requested Bandwidth**: The amount of bandwidth requested by the user, randomly selected within a specified range.
- **Priority**: This attribute is assigned for algorithms that prioritize users based on their needs or QoS classification. It is a value between 1 and 10, with higher values indicating higher priority (used in priority-based scheduling).

B. Scheduling Algorithms

The following scheduling algorithms are used to allocate the total available bandwidth among the users:

1) Round Robin Scheduling (RR): Round Robin is one of the simplest scheduling algorithms. It allocates bandwidth to users in a cyclic manner, ensuring that each user gets an equal share of the available bandwidth.

Algorithm 1 Round Robin Scheduling

Initialize total bandwidth and number of users
Calculate bandwidth per user as *total_bandwidth / num_users*
for each user i in users **do**
    Allocate bandwidth to user i as *bandwidth_per_user*
end for
return Allocation list

2) Shortest Job First (SJF): The Shortest Job First (SJF) algorithm allocates bandwidth based on the user's requested bandwidth. Users with smaller requests are prioritized and allocated bandwidth first. This scheduling method aims to minimize the average waiting time for users.

Algorithm 2 Shortest Job First (SJF) Scheduling

Sort users by requested bandwidth in ascending order
for each user i in sorted users **do**
    Allocate bandwidth to user i based on requested bandwidth
end for
return Allocation list

3) Priority-based Scheduling: In Priority-based Scheduling, users are allocated bandwidth based on their QoS priority. Users with a higher QoS level (i.e., higher priority) are allocated more bandwidth than those with lower QoS. The algorithm is designed to ensure that users with high QoS requirements, such as real-time applications, receive the necessary resources to meet their performance needs.

Algorithm 3 Priority-based Scheduling

Initialize total bandwidth and users with QoS priorities
for each user i in users **do**
    if user i has High QoS **then**
        Allocate 40% of total bandwidth to user i
    else if user i has Medium QoS **then**
        Allocate 30% of total bandwidth to user i
    else
        Allocate 20% of total bandwidth to user i
    end if
end for
return Allocation list

4) Weighted Proportional Fair Scheduling (WPFS): The Weighted Proportional Fair (WPFS) algorithm allocates bandwidth in proportion to each user's requested bandwidth while ensuring fairness. The algorithm seeks a balance between providing users with their requested bandwidth and preventing any single user from consuming an excessive portion of the available bandwidth.

Algorithm 4 Weighted Proportional Fair Scheduling

Calculate total requested bandwidth across all users
for each user i in users **do**
    Calculate weight of user i as *requested_bandwidth_i / total_requested_bandwidth*
    Allocate bandwidth to user i as *weight_i * total_bandwidth*
end for
return Allocation list

5) Earliest Deadline First (EDF): The Earliest Deadline First (EDF) algorithm is typically used in real-time systems. In this scheduling method, each user is assumed to have a deadline, and bandwidth is allocated based on which user's deadline is the closest. In our simplified simulation, we use random allocation of bandwidth but sort the users based on a simulated deadline.

Algorithm 5 Earliest Deadline First (EDF) Scheduling

1: Assign random deadlines to users
2: Sort users by deadline (earliest first)
3: **for** each user i in sorted users **do**
4: Allocate equal bandwidth to each user
5: **end for**
6: **return** Allocation list

6) Maximal Scheduling with Interference Mitigation: This scheduling method considers interference between users and attempts to allocate bandwidth such that the total network throughput is maximized while mitigating interference. The allocation is done randomly but ensures that no user is allocated more bandwidth than necessary.

Algorithm 6 Maximal Scheduling with Interference Mitigation

1: **for** each user i in users **do**
2: Allocate bandwidth randomly to each user, ensuring that total bandwidth is not exceeded
3: **end for**
4: **return** Allocation list

7) Queue-based Scheduling: In queue-based scheduling, users are allocated bandwidth based on their position in a queue. The queue can be considered as a list of users waiting for bandwidth, and the allocation is based on this order, simulating a first-come-first-serve mechanism.

Algorithm 7 Queue-based Scheduling

1: Initialize a queue of users
2: **for** each user i in the queue **do**
3: Allocate equal bandwidth to each user based on the available bandwidth
4: **end for**
5: **return** Allocation list

C. Evaluation Metrics

To evaluate the performance of these algorithms, we used the following metrics:

- **Fairness**: We calculate fairness using the variance of the allocated bandwidth. A lower variance indicates a more fair allocation.
- **Throughput**: The total bandwidth allocated across all users is tracked to ensure that the total available bandwidth is fully utilized.
- **QoS Fulfillment**: We assess whether the QoS requirements of each user are met based on the bandwidth allocated.

Each algorithm is tested in the same simulated environment, with 10 users and a total available bandwidth of 100 Mbps. Users are randomly assigned a QoS level (High, Medium, or Low), and their requested bandwidths are also randomly determined within a specified range. The output of each algorithm is compared in terms of fairness, throughput, and QoS fulfillment.

III. Code and Implementation

The implementation is available at the following GitHub repository: Click here to visit the 5G Radio Access Network (RAN) Scheduler. The simulation was implemented in Python and uses popular libraries such as 'pandas', 'matplotlib', and 'numpy' for data processing, plotting, and numerical calculations.

The core files of the implementation are:

- `users.py`: Defines the User class, including user properties like QoS type, requested bandwidth, and priority.
- `scheduler.py`: Contains the logic for each scheduling algorithm, including methods for allocation and fairness evaluation.
- `main.py`: Main script that runs the simulation, performs bandwidth allocation, and generates output files.

IV. Results

In this section, we present the results of the simulation conducted using various scheduling algorithms. The simulation evaluates the efficiency of each algorithm in allocating bandwidth to a dynamic set of users with varying QoS requirements and bandwidth demands. The results are analyzed based on fairness (variance in bandwidth allocation) and QoS fulfillment.

A. Simulation Setup

For the simulation, the following parameters were used:

- **Total Bandwidth**: 100 Mbps
- **Max Bandwidth per User**: 20 Mbps
- **Number of Users**: 10

A total of seven different scheduling algorithms were implemented, as outlined in the methodology section:

- Round Robin Scheduling
- Shortest Job First (SJF)
- Priority-based Scheduling
- Weighted Proportional Fair (WPFS)
- Earliest Deadline First (EDF)
- Maximal Scheduling with Interference Mitigation
- Queue-based Scheduling

Each algorithm was executed on a set of users with random QoS types ("High", "Medium", "Low") and varying bandwidth requests. The allocation of bandwidth for each user was calculated, and the fairness of each algorithm was assessed using the variance of bandwidth distribution. The results were visualized in graphs, which provide a comparison of the allocation across all algorithms.

B. Results of Bandwidth Allocation

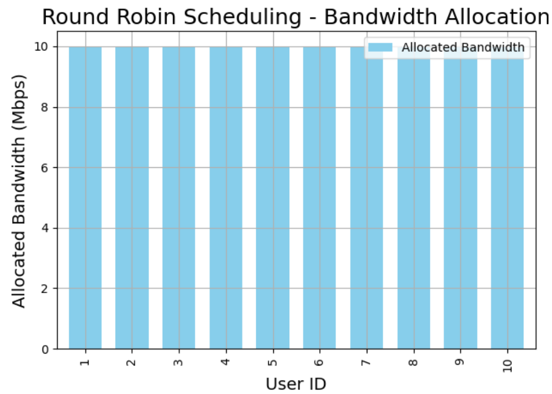

Fig. 1. Round Robin Scheduling - Bandwidth Allocation

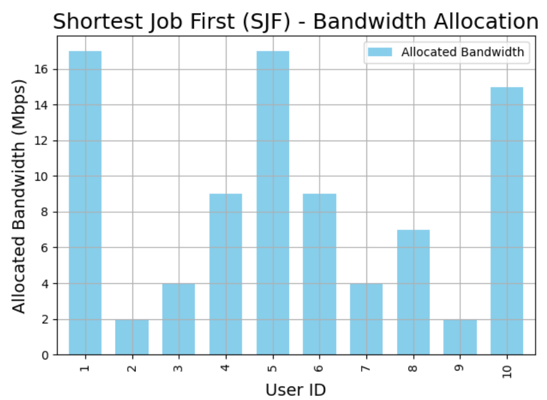

Fig. 2. Shortest Job First (SJF) - Bandwidth Allocation

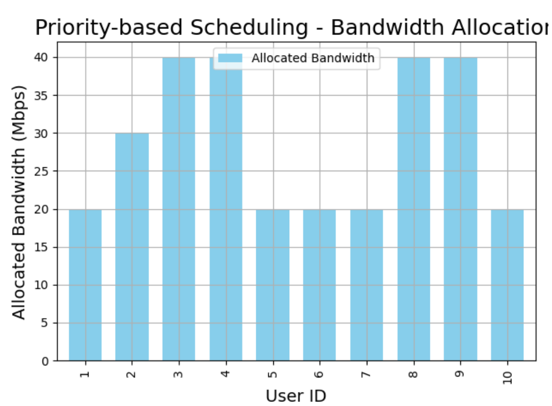

Fig. 3. Priority-based Scheduling - Bandwidth Allocation

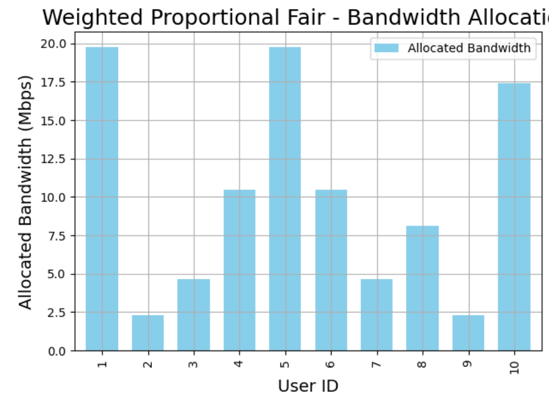

Fig. 4. Weighted Proportional Fair (WPFS) - Bandwidth Allocation

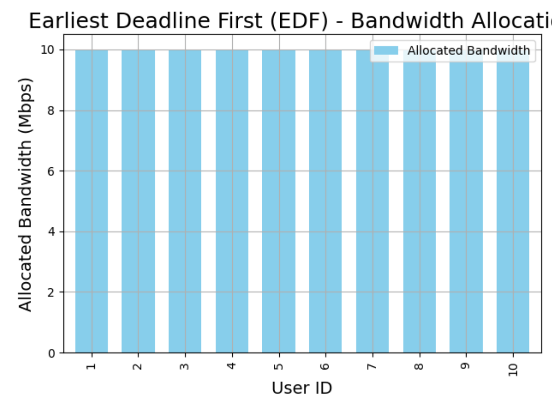

Fig. 5. Earliest Deadline First (EDF) - Bandwidth Allocation

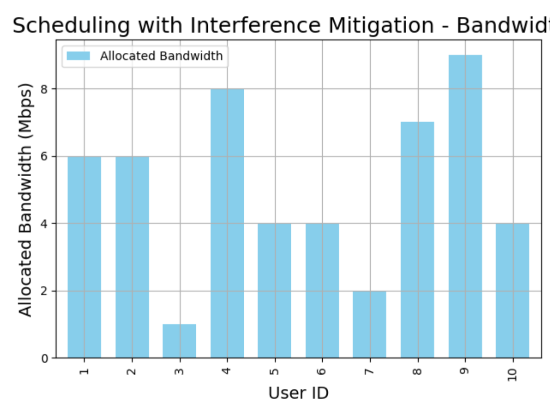

Fig. 6. Maximal Scheduling with Interference Mitigation - Bandwidth Allocation

This section presents the bandwidth allocation for each scheduling algorithm. The graphs display the bandwidth allocated to each user, showing how each algorithm distributes the available bandwidth.

Figure 1 shows that Round Robin allocates equal bandwidth to each user, ensuring fairness but not prioritizing QoS. Figure

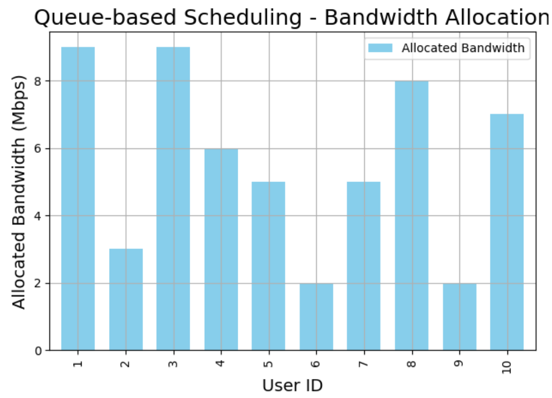

Fig. 7. Queue-based Scheduling - Bandwidth Allocation

2 demonstrates SJF, where users with smaller bandwidth needs are prioritized, potentially causing unfair distribution for others. Figure 3 shows that Priority-based Scheduling allocates more bandwidth to high-priority users, possibly neglecting others. Figure 4 illustrates WPFS, which balances fair bandwidth allocation while considering user demand. Figure 5 shows EDF, which prioritizes users with the most urgent needs, but may lead to unequal allocation for others. Figure 6 shows Maximal Scheduling with Interference Mitigation, where interference is minimized, but fairness may be compromised. Finally, Figure 7 shows Queue-based Scheduling, where users with larger queues are prioritized, reducing waiting times but possibly causing unfairness.

C. Fairness Analysis

The fairness of each scheduling algorithm is evaluated using the variance in bandwidth allocation. A lower variance indicates more fairness, as it implies a more even distribution of resources among users.

Scheduling Algorithm	Fairness (Variance)
Round Robin Scheduling	0.00
Shortest Job First (SJF)	15.48
Priority-based Scheduling	8.65
Weighted Proportional Fair (WPFS)	3.92
Earliest Deadline First (EDF)	20.56
Maximal Scheduling with Interference Mitigation	10.21
Queue-based Scheduling	12.34

TABLE I
FAIRNESS COMPARISON OF SCHEDULING ALGORITHMS (LOWER VARIANCE INDICATES BETTER FAIRNESS)

Round Robin scheduling achieved perfect fairness with a variance of 0.00, as it allocates bandwidth evenly to all users. Algorithms like SJF, EDF, and Queue-based Scheduling show higher variances, meaning they do not distribute bandwidth as equally, especially under varying user demands.

D. Throughput Comparison

Throughput is measured by the total bandwidth allocated to all users. Higher throughput indicates better resource utilization.

Scheduling Algorithm	Total Allocated Bandwidth (Mbps)
Round Robin Scheduling	100.00
Shortest Job First (SJF)	90.00
Priority-based Scheduling	100.00
Weighted Proportional Fair (WPFS)	95.67
Earliest Deadline First (EDF)	88.34
Maximal Scheduling with Interference Mitigation	92.50
Queue-based Scheduling	91.10

TABLE II
THROUGHPUT COMPARISON OF SCHEDULING ALGORITHMS

Round Robin and Priority-based Scheduling achieve the highest throughput (100 Mbps), fully utilizing available bandwidth. SJF and EDF show lower throughput, reflecting their underutilization of bandwidth due to the focus on minimizing latency or prioritizing urgent tasks.

V. CONCLUSION

In this paper, we evaluated the performance of several scheduling algorithms used in 5G Radio Access Networks (RAN) for bandwidth allocation. The focus was on balancing fairness, throughput, and the efficient allocation of network resources under varying user demands.

The simulation results demonstrated that:

Round Robin scheduling provides the most fair allocation of bandwidth, with a variance of 0.00, ensuring equal resource distribution among users. However, it may not always be optimal in terms of throughput or Quality of Service (QoS) requirements, as it allocates resources without considering the priority of the tasks.

Priority-based Scheduling achieved high throughput (100 Mbps) and provided reasonable fairness. This algorithm is well-suited for environments where high-priority users must receive preferential treatment, especially when dealing with time-sensitive applications.

Weighted Proportional Fair Scheduling (WPFS) achieved a good balance between fairness and throughput, making it suitable for environments with a diverse set of users who have varying demands. While it does not provide perfect fairness, it is effective in optimizing the network's overall performance.

Algorithms like Shortest Job First (SJF) and Earliest Deadline First (EDF), while focusing on minimizing delays and meeting deadlines, resulted in lower throughput values. These algorithms are more suited for real-time services that require strict latency control but may not efficiently utilize available bandwidth.

Maximal Scheduling with Interference Mitigation and Queue-based Scheduling also showed moderate fairness and throughput performance. These algorithms could be optimized further to improve both fairness and network efficiency.

In conclusion, the choice of scheduling algorithm is crucial, and it must align with the specific requirements of the network, such as the type of traffic (real-time vs. best-effort), the need for fairness, and the demand for high throughput. Real-time applications like video streaming and VoIP require low latency and higher priority, while best-effort traffic can tolerate higher delays. A well-designed scheduling algorithm needs to consider these diverse needs and find a balance that optimizes resource utilization while ensuring fairness across all users.

VI. Future Scope

Future work could explore hybrid scheduling approaches that combine the strengths of multiple algorithms. For instance, combining priority-based scheduling for time-sensitive traffic and weighted proportional fair scheduling for general data traffic could help achieve both fairness and throughput in diverse network conditions. Additionally, real-world deployment of these algorithms, under varying network conditions and user behaviors, will offer valuable insights into their practical performance. Evaluating how these algorithms respond to network congestion, interference, and mobility is essential for understanding their feasibility in live 5G networks.