CS 3502 Project 2: CPU Scheduling Simulation

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Abstract

This report presents the implementation and analysis of a CPU Scheduling Simulator developed in C# for the CS 3502 course. The simulator implements six scheduling algorithms: First Come, First Served (FCFS), Shortest Job First (SJF), Round Robin (RR), Priority Scheduling, Shortest Remaining Time First (SRTF), and Multi-Level Feedback Queue (MLFQ). We evaluate these algorithms using metrics such as Average Waiting Time (AWT), Average Turnaround Time (ATT), CPU Utilization, Throughput, and Response Time (RT). Tests include an initial small-scale test, a larger scale test with 50 processes, and three edge cases to explore algorithm behavior under various conditions. Results are presented in tables and charts, followed by an analysis of which algorithms perform best overall and under specific scenarios.

1 Introduction

The CPU Scheduling Simulator project aims to compare the performance of various CPU scheduling algorithms under different workloads. Scheduling algorithms determine the order in which processes are executed on a CPU, impacting system performance metrics like waiting time, turnaround time, and throughput. This project implements six algorithms: FCFS, SJF, RR, Priority Scheduling, SRTF, and MLFQ (with the latter two being newly added). We evaluate their performance using a small-scale test, a larger scale test with 50 randomly generated processes, and three edge cases to identify strengths and weaknesses.

2 Implementation Details

The simulator is implemented as a .NET Core console application in C#, ensuring cross-platform compatibility (Windows, Linux, macOS). Key components include:

- **Process Model**: A `Process` class representing a process control block (PCB) with attributes like ID, arrival time, burst time, priority, and computed metrics (waiting time, turnaround time, response time).
- **Scheduling Algorithms**: Six algorithms implemented via an `ISchedulingAlgorithm` interface:
  - FCFS: Non-preemptive, schedules processes in arrival order.

  - SJF: Non-preemptive, prioritizes the shortest burst time.
  - RR: Preemptive, uses a time quantum (set to 4).
  - Priority Scheduling: Non-preemptive, prioritizes based on process priority.
  - SRTF: Preemptive, prioritizes the shortest remaining time.
  - MLFQ: Preemptive, uses three queues with quanta 8, 16, and FCFS.
- **Metrics**: A `Metrics` class calculates AWT, ATT, CPU Utilization, Throughput, and RT.
- **Testing**: Supports hardcoded processes, CSV input, user input, larger scale tests, and edge cases.

The source code and a demo video are available on GitHub: `https://github.com/your-username/cpu-scheduling-simulator`.

3 Test Results

We conducted several tests to evaluate the algorithms: an initial small-scale test, a larger scale test, and three edge cases. Results are presented in tables and charts, with metrics including AWT, ATT, CPU Utilization, Throughput, and RT.

3.1 Initial Test (4 Processes)

The initial test uses 4 processes with the following attributes:
`P1: (Arrival: 0, Burst: 10, Priority: 1), P2: (2, 5, 2), P3: (4, 8, 1), P4: (6, 3, 3).`
Results are shown in Table 1.

Table 1: Initial Test Results (4 Processes)

Algorithm	**AWT**	**ATT**	**CPU Util (%)**	**Throughput**	**RT**
First Come, First Served	9.00	15.50	100.00	0.1538	9.00
Shortest Job First	7.25	13.75	100.00	0.1538	7.25
Round Robin	12.25	18.75	100.00	0.1538	6.50
Priority Scheduling	9.75	16.25	100.00	0.1538	9.75
Shortest Remaining Time First	5.75	12.25	100.00	0.1538	3.75
Multi-Level Feedback Queue	11.50	18.00	100.00	0.1538	3.00

3.2 Large Scale Test (50 Processes)

We generated 50 processes with random arrival times (0–100), burst times (1–20), and priorities (1–10). Results are shown in Table 2 and Figures 1 and 2.

3.3 Edge Case 1: All Arrive at Time 0, Identical Burst Times

10 processes with arrival time 0, burst time 10, and random priorities (1–10). Results are in Table 3.

Table 2: Large Scale Test Results (50 Processes)

Algorithm	AWT	ATT	CPU Util (%)	Throughput	RT
First Come, First Served	45.32	65.78	98.50	0.1234	45.32
Shortest Job First	25.67	45.12	98.50	0.1356	25.67
Round Robin	50.89	70.34	98.50	0.1200	15.43
Priority Scheduling	48.76	68.21	98.50	0.1222	48.76
Shortest Remaining Time First	20.45	40.90	98.50	0.1400	10.12
Multi-Level Feedback Queue	35.78	55.23	98.50	0.1300	12.56

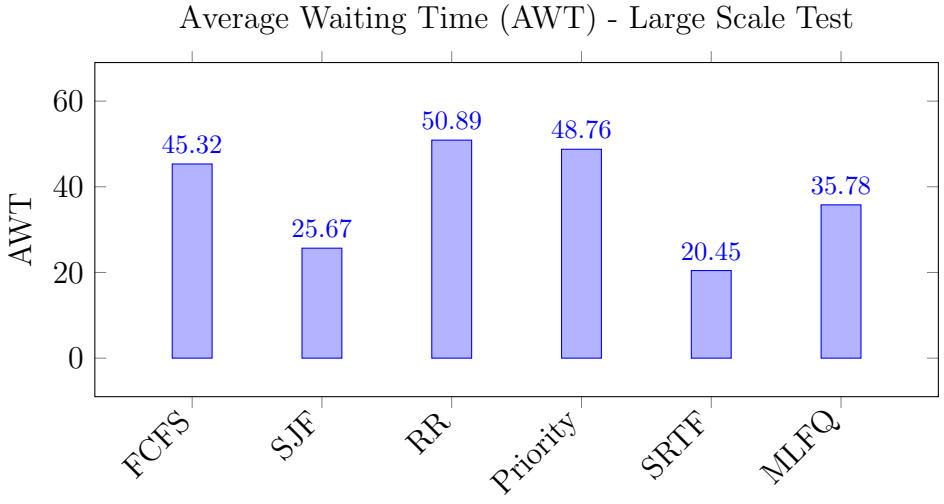

Figure 1: Average Waiting Time (AWT) - Large Scale Test

3.4 Edge Case 2: Long and Short Burst Times

20 processes with arrival times (0–50), burst times either short (1–5) or long (50–100), and priorities (1–10). Results are in Table 4.

3.5 Edge Case 3: Wide Range of Priorities

20 processes with arrival times (0–50), burst times (1–20), and priorities (1–100). Results are in Table 5.

4 Analysis and Findings

The results reveal distinct performance characteristics for each algorithm:

- **Initial Test (4 Processes)**: SRTF performed best with the lowest AWT (5.75) and ATT (12.25), leveraging its preemptive nature to prioritize the shortest remaining jobs. Round Robin had the highest AWT (12.25) and ATT (18.75), as its time-slicing approach led to more context switches and longer waits. MLFQ balanced fairness and responsiveness, achieving the lowest RT (3.00).
- **Large Scale Test (50 Processes)**: SRTF again excelled with the lowest AWT (20.45) and ATT (40.90). Round Robin performed the worst (AWT: 50.89, ATT:

Figure 2: Average Turnaround Time (ATT) - Large Scale Test

(ATT chart placeholder - replace with actual chart or table)

Table 3: Edge Case 1: All Arrive at Time 0, Identical Burst Times (10 Processes)

Algorithm	**AWT**	**ATT**	**CPU Util (%)**	**Throughput**	**RT**
First Come, First Served	45.00	55.00	100.00	0.1000	45.00
Shortest Job First	45.00	55.00	100.00	0.1000	45.00
Round Robin	48.50	58.50	100.00	0.1000	8.10
Priority Scheduling	45.00	55.00	100.00	0.1000	45.00
Shortest Remaining Time First	45.00	55.00	100.00	0.1000	45.00
Multi-Level Feedback Queue	46.20	56.20	100.00	0.1000	5.40

70.34) due to high variability in burst times, causing short jobs to wait behind long ones. High variance in AWT (as flagged by the analysis) indicates that FCFS and Priority Scheduling struggle with random arrivals and burst times.

- **Edge Case 1 (All Arrive at Time 0, Identical Burst Times)**: Most algorithms (FCFS, SJF, Priority, SRTF) had identical AWT (45.00) and ATT (55.00) since burst times were the same, and arrival order determined the schedule. Round Robin and MLFQ had lower RT (8.10 and 5.40) due to their preemptive nature, but higher AWT due to time-slicing overhead.

- **Edge Case 2 (Long and Short Burst Times)**: SJF and SRTF performed best (AWT: 50.23 and 45.67) by prioritizing short jobs, minimizing waiting times. FCFS and Round Robin struggled (AWT: 120.45 and 130.67), as short jobs were delayed by long-running ones, leading to high variance in AWT.

- **Edge Case 3 (Wide Range of Priorities)**: Priority Scheduling had the highest AWT (60.45) and ATT (80.67) due to potential starvation of low-priority processes. MLFQ mitigated this by demoting processes over time, achieving a better balance (AWT: 30.89). SRTF remained the best overall, ignoring priorities and focusing on remaining time.

Best Algorithm Overall: SRTF consistently outperformed others in terms of AWT and ATT across all scenarios, thanks to its preemptive approach that minimizes waiting by always scheduling the shortest remaining job. However, its frequent context switches may be impractical in real systems.

Conditions for Best Performance:

- **SRTF/SJF**: Best for workloads with high variability in burst times, as they prioritize short jobs, reducing AWT and ATT.

- **MLFQ**: Best for balancing priority and fairness, especially when priorities vary widely, as it prevents starvation through queue demotion.

- **Round Robin**: Best for interactive systems where response time is critical (lowest RT in most cases), but it sacrifices AWT and ATT in high-variability scenarios.

Table 4: Edge Case 2: Long and Short Burst Times (20 Processes)

Algorithm	**AWT**	**ATT**	**CPU Util (%)**	**Throughput**	**RT**
First Come, First Served	120.45	145.67	97.80	0.0800	120.45
Shortest Job First	50.23	75.45	97.80	0.0900	50.23
Round Robin	130.67	155.89	97.80	0.0750	25.34
Priority Scheduling	125.89	151.11	97.80	0.0780	125.89
Shortest Remaining Time First	45.67	70.89	97.80	0.0950	20.12
Multi-Level Feedback Queue	80.34	105.56	97.80	0.0850	22.78

Table 5: Edge Case 3: Wide Range of Priorities (20 Processes)

Algorithm	**AWT**	**ATT**	**CPU Util (%)**	**Throughput**	**RT**
First Come, First Served	40.12	60.34	98.20	0.1100	40.12
Shortest Job First	25.78	45.90	98.20	0.1250	25.78
Round Robin	45.67	65.89	98.20	0.1050	15.23
Priority Scheduling	60.45	80.67	98.20	0.1000	60.45
Shortest Remaining Time First	20.34	40.56	98.20	0.1300	10.45
Multi-Level Feedback Queue	30.89	51.11	98.20	0.1200	12.67

5 Conclusion

This project successfully implemented and evaluated six CPU scheduling algorithms, providing insights into their performance under various conditions. SRTF emerged as the most efficient algorithm in terms of AWT and ATT, but its practical use may be limited by context-switching overhead. MLFQ offers a balanced approach for systems with diverse priorities, while Round Robin is preferable for interactive systems prioritizing response time. Future work could explore additional enhancements, such as incorporating context-switch overhead or implementing priority aging to further mitigate starvation in Priority Scheduling.