CHAPTER 5

Process Scheduling

CPU scheduling is the basis of multiprogrammed operating systems. By switching the CPU among processes, the operating system can make the computer more productive. In this chapter, we introduce the basic scheduling concepts and discuss in great length CPU scheduling. FCFS, SJF, Round-Robin, Priority, and the other scheduling algorithms should be familiar to the students. This is their first exposure to the idea of resource allocation and scheduling, so it is important that they understand how it is done. Gantt charts, simulations, and play acting are valuable ways to get the ideas across. Show how the ideas are used in other situations (like waiting in line at a post office, a waiter time sharing between customers, even classes being an interleaved round-robin scheduling of professors).

A simple project is to write several different CPU schedulers and compare their performance by simulation. The source of CPU and I/O bursts may be generated by random number generators or by a trace tape. The instructor can make up the trace tape in advance to provide the same data for all students. The file that I used was a set of jobs, each job being a variable number of alternating CPU and I/O bursts. The first line of a job was the word JOB and the job number. An alternating sequence of CPU n and I/O n lines followed, each specifying a burst time. The job was terminated by an END line with the job number again. Compare the time to process a set of jobs using FCFS, Shortest-Burst-Time, and round-robin scheduling. Round-robin is more difficult, since it requires putting unfinished requests back in the ready queue.

5.1 I/O-bound programs have the property of performing only a small amount of computation before performing I/O. Such programs typically do not use up their entire CPU quantum. CPU-bound programs, on the other hand, use their entire quantum without performing any blocking I/O operations. Consequently, one could make better use of the computer's resouces by giving higher priority to I/O-bound programs and allow them to execute ahead of the CPU-bound programs.

5.2 $n!$ (n factorial $= n \times n-1 \times n-2 \times \ldots \times 2 \times 1$).

5.3 a. The time quantum is 1 millisecond: Irrespective of which process is scheduled, the scheduler incurs a 0.1 millisecond

context-switching cost for every context-switch. This results in a CPU utilization of $1/1.1 * 100 = 91\%$.

b. The time quantum is 10 milliseconds: The I/O-bound tasks incur a context switch after using up only 1 millisecond of the time quantum. The time required to cycle through all the processes is therefore $10*1.1 + 10.1$ (as each I/O-bound task executes for 1 millisecond and then incur the context switch task, whereas the CPU-bound task executes for 10 milliseconds before incurring a context switch). The CPU utilization is therefore $20/21.1 * 100 = 94\%$.

5.4 Processes that need more frequent servicing, for instance, interactive processes such as editors, can be in a queue with a small time quantum. Processes with no need for frequent servicing can be in a queue with a larger quantum, requiring fewer context switches to complete the processing, and thus making more efficient use of the computer.

5.5 The program could maximize the CPU time allocated to it by not fully utilizing its time quantums. It could use a large fraction of its assigned quantum, but relinquish the CPU before the end of the quantum, thereby increasing the priority associated with the process.

5.6 a. 160 and 40

b. 35

c. 54

5.7 a. FCFS—discriminates against short jobs since any short jobs arriving after long jobs will have a longer waiting time.

b. RR—treats all jobs equally (giving them equal bursts of CPU time) so short jobs will be able to leave the system faster since they will finish first.

c. Multilevel feedback queues work similar to the RR algorithm—they discriminate favorably toward short jobs.

5.8 When $\alpha = 0$ and $\tau_0 = 100$ milliseconds, the formula always makes a prediction of 100 milliseconds for the next CPU burst. When $\alpha = 0.99$ and $\tau_0 = 10$ milliseconds, the most recent behavior of the process is given much higher weight than the past history associated with the process. Consequently, the scheduling algorithm is almost memoryless, and simply predicts the length of the previous burst for the next quantum of CPU execution.

5.9 Shortest job first and priority-based scheduling algorithms could result in starvation.

5.10 It will favor the I/O-bound programs because of the relatively short CPU burst request by them; however, the CPU-bound programs will not starve because the I/O-bound programs will relinquish the CPU relatively often to do their I/O.

5.11 a. 26

b. 8

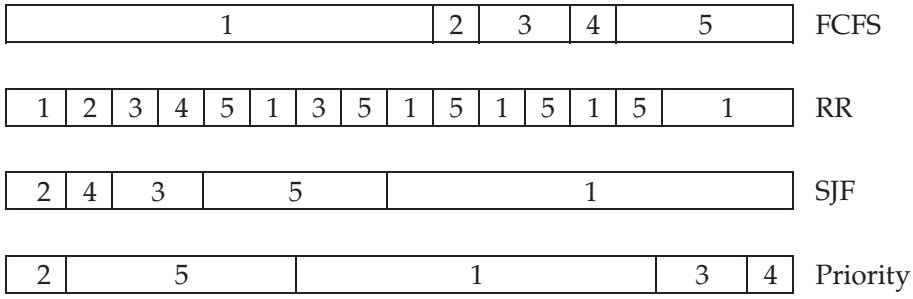
c. 14

5.12 a. In effect, that process will have increased its priority since by getting time more often it is receiving preferential treatment.

b. The advantage is that more important jobs could be given more time, in other words, higher priority in treatment. The consequence, of course, is that shorter jobs will suffer.

c. Allot a longer amount of time to processes deserving higher priority. In other words, have two or more quantums possible in the Round-Robin scheme.

5.13 a. The four Gantt charts are



b. Turnaround time

	FCFS	RR	SJF	Priority
P_1	10	19	19	16
P_2	11	2	1	1
P_3	13	7	4	18
P_4	14	4	2	19
P_5	19	14	9	6

c. Waiting time (turnaround time minus burst time)

	FCFS	RR	SJF	Priority
P_1	0	9	9	6
P_2	10	1	0	0
P_3	11	5	2	16
P_4	13	3	1	18
P_5	14	9	4	1

d. Shortest Job First

5.14 The priorities assigned to the processes are 80, 69, and 65 respectively. The scheduler lowers the relative priority of CPU-bound processes.

5.15 a. CPU utilization and response time: CPU utilization is increased if the overheads associated with context switching is minimized. The

context switching overheads could be lowered by performing context switches infrequently. This could, however, result in increasing the response time for processes.

b. Average turnaround time and maximum waiting time: Average turnaround time is minimized by executing the shortest tasks first. Such a scheduling policy could, however, starve long-running tasks and thereby increase their waiting time.

c. I/O device utilization and CPU utilization: CPU utilization is maximized by running long-running CPU-bound tasks without performing context switches. I/O device utilization is maximized by scheduling I/O-bound jobs as soon as they become ready to run, thereby incurring the overheads of context switches.

5.16 a. FCFS

b. LIFO

5.17 a. 10.53

b. 9.53

c. 6.86

Remember that turnaround time is finishing time minus arrival time, so you have to subtract the arrival times to compute the turnaround times. FCFS is 11 if you forget to subtract arrival time.