Uniprocessor Scheduling

Chapter 9

1

Aim of Scheduling

- Assign processes to be executed by the processor(s)
- Response time
- Throughput
- Processor efficiency

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Table 9.1 Types of Scheduling

Long-term scheduling	The decision to add to the pool of processes to be executed
Medium-term scheduling	The decision to add to the number of processes that are partially or fully in main memory
Short-term scheduling	The decision as to which available process will be executed by the processor
I/O scheduling	The decision as to which process's pending I/O request shall be handled by an available I/O device

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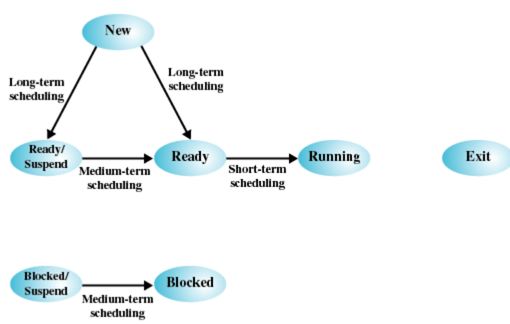

Figure 9.1 Scheduling and Process State Transitions

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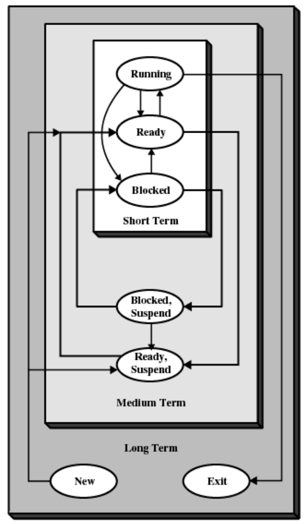

Figure 9.2 Levels of Scheduling

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Long-Term Scheduling

- Determines which programs are admitted to the system for processing
- Controls the degree of multiprogramming
- More processes, smaller percentage of time each process is executed

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Medium-Term Scheduling

- Part of the swapping function
- Based on the need to manage the degree of multiprogramming

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Short-Term Scheduling

- Known as the dispatcher
- Executes most frequently
- Invoked when an event occurs
  - Clock interrupts
  - I/O interrupts
  - Operating system calls
  - Signals

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Short-Tem Scheduling Criteria

- User-oriented
  - Response Time
    - Elapsed time between the submission of a request until there is output.
- System-oriented
  - Effective and efficient utilization of the processor

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Short-Term Scheduling Criteria

- Performance-related
  - Quantitative
  - Measurable such as response time and throughput

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Table 9.2 Scheduling Criteria

User Oriented, Performance Related

Turnaround time This is the interval of time between the submission of a process and its completion. Includes actual execution time plus time spent waiting for resources, including the processor. This is an appropriate measure for a batch job.

Response time For an interactive process, this is the time from the submission of a request until the response begins to be received. Often a process can begin producing some output to the user while continuing to process the request. Thus, this is a better measure than turnaround time from the user's point of view. The scheduling discipline should attempt to achieve low response time and to maximize the number of interactive users receiving acceptable response time.

Deadlines When process completion deadlines can be specified, the scheduling discipline should subordinate other goals to that of maximizing the percentage of deadlines met.

User Oriented, Other

Predictability A given job should run in about the same amount of time and at about the same cost regardless of the load on the system. A wide variation in response time or turnaround time is distracting to users. It may signal a wide swing in system workloads or the need for system tuning to cure instabilities.

System Oriented, Performance Related

Throughput The scheduling policy should attempt to maximize the number of processes completed per unit of time. This is a measure of how much work is being performed. This clearly depends on the average length of a process but is also influenced by the scheduling policy, which may affect utilization.

Processor utilization This is the percentage of time that the processor is busy. For an expensive shared system, this is a significant criterion. In single-user systems and in some other systems, such as real-time systems, this criterion is less important than some of the others.

System Oriented, Other

Fairness In the absence of guidance from the user or other system-supplied guidance, processes should be treated the same, and no process should suffer starvation.

Enforcing priorities When processes are assigned priorities, the scheduling policy should favor higher-priority processes.

Balancing resources The scheduling policy should keep the resources of the system busy. Processes that will underutilize stressed resources should be favored. This criterion also involves medium-term and long-term scheduling.

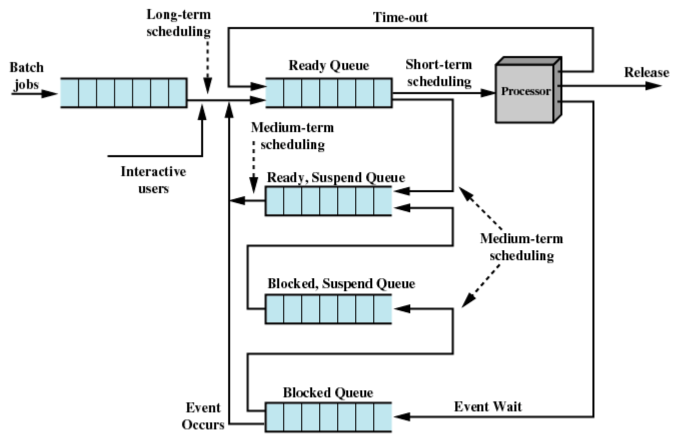

Figure 9.3 Queuing Diagram for Scheduling

Priorities

- Scheduler will always choose a process of higher priority over one of lower priority
- Have multiple ready queues to represent each level of priority
- Lower-priority may suffer starvation
  – Allow a process to change its priority based on its age or execution history

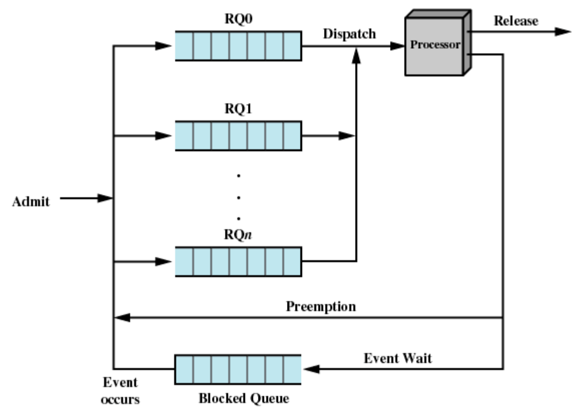

Figure 9.4 Priority Queuing

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Decision Mode

- Nonpreemptive
  - Once a process is in the running state, it will continue until it terminates or blocks itself for I/O
- Preemptive
  - Currently running process may be interrupted and moved to the Ready state by the operating system
  - Allows for better service since any one process cannot monopolize the processor for very long

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Process Scheduling Example

Table 9.4 Process Scheduling Example

Process	Arrival Time	Service Time
A	0	3
B	2	6
C	4	4
D	6	5
E	8	2

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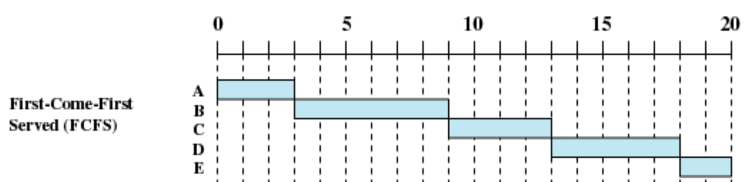
First-Come-First-Served (FCFS)



- Each process joins the Ready queue
- When the current process ceases to execute, the oldest process in the Ready queue is selected

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First-Come-First-Served (FCFS)

- A short process may have to wait a very long time before it can execute
- Favors CPU-bound processes
  - I/O processes have to wait until CPU-bound process completes

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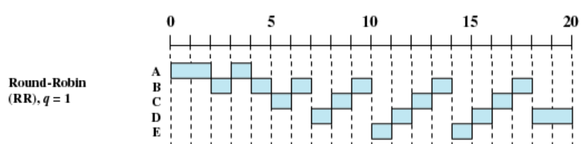
Round-Robin



- Uses preemption based on a clock
- An amount of time is determined that allows each process to use the processor for that length of time

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Round-Robin

- Clock interrupt is generated at periodic intervals
- When an interrupt occurs, the currently running process is placed in the read queue
  - Next ready job is selected
- Known as time slicing

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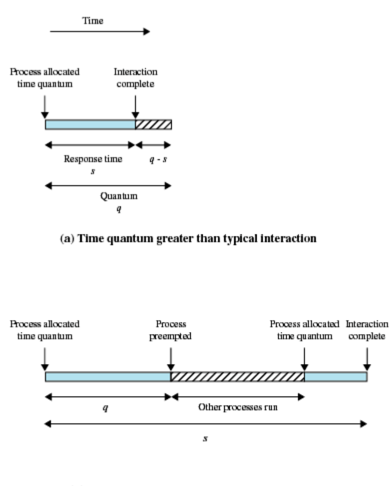

Figure 9.6 Effect of Size of Preemption Time Quantum

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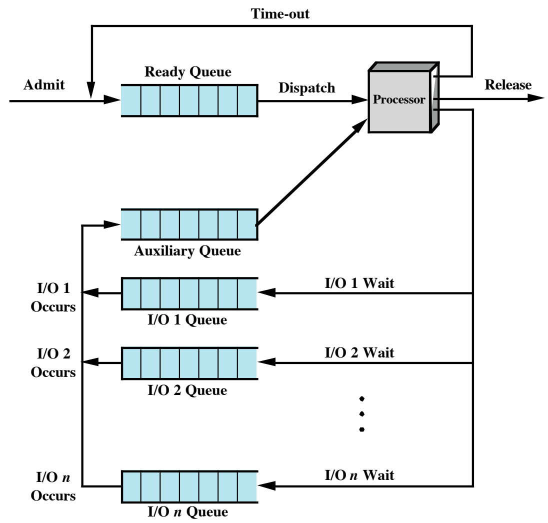

Figure 9.7 Queuing Diagram for Virtual Round-Robin Scheduler

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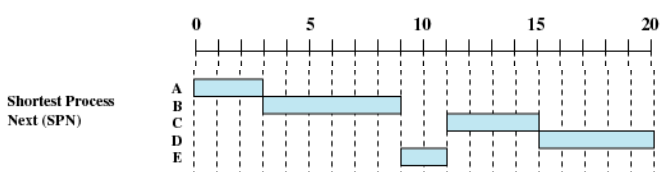
Shortest Process Next



- Nonpreemptive policy
- Process with shortest expected processing time is selected next
- Short process jumps ahead of longer processes

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Shortest Process Next

- Predictability of longer processes is reduced
- If estimated time for process not correct, the operating system may abort it
- Possibility of starvation for longer processes

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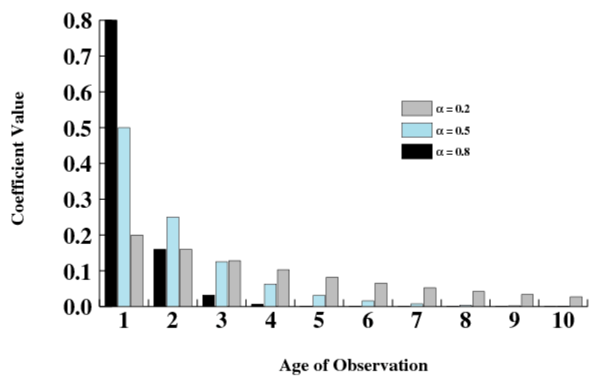

Figure 9.8 Exponential Smoothing Coefficients

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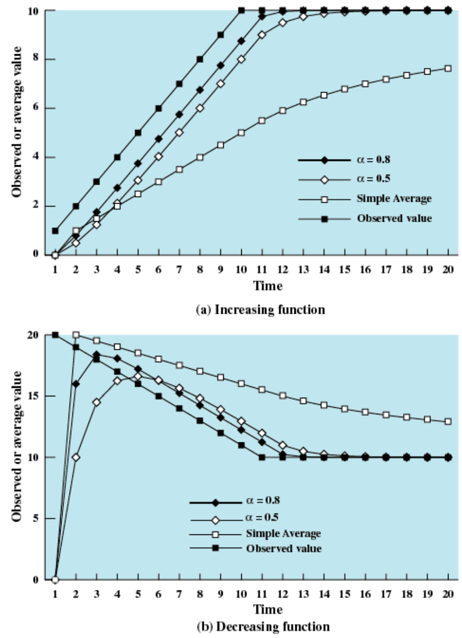

Figure 9.9 Use of Exponential Averaging

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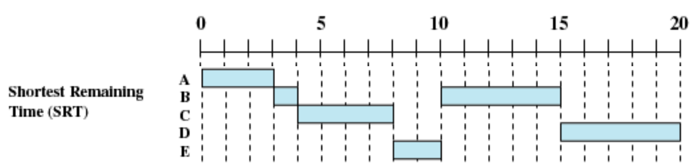
Shortest Remaining Time



- Preemptive version of shortest process next policy
- Must estimate processing time

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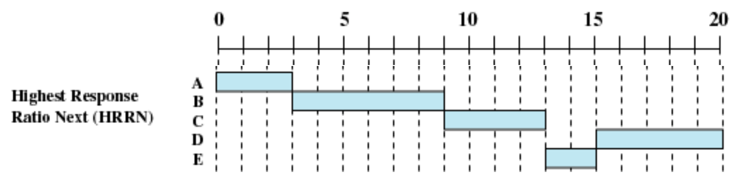
Highest Response Ratio Next (HRRN)



- Choose next process with the greatest ratio

time spent waiting + expected service time
expected service time

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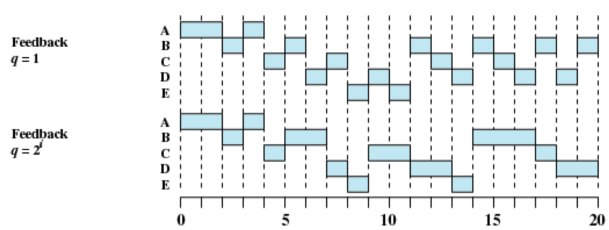
Feedback



- Penalize jobs that have been running longer
- Don't know remaining time process needs to execute

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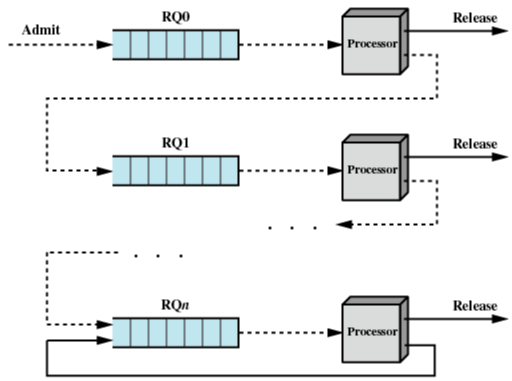

Figure 9.10 Feedback Scheduling

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Table 9.3 Characteristics of Various Scheduling Policies

	Selection Function	Decision Mode	Throughput	Response Time	Overhead	Effect on Processes	Starvation
FCFS	max[w]	Nonpreemptive	Not emphasized	May be high, especially if there is a large variance in process execution times	Minimum	Penalizes short processes; penalizes I/O bound processes	No
Round Robin	constant	Preemptive (at time quantum)	May be low if quantum is too small	Provides good response time for short processes	Minimum	Fair treatment	No
SPN	min[s]	Nonpreemptive	High	Provides good response time for short processes	Can be high	Penalizes long processes	Possible
SRT	min[$s - e$]	Preemptive (at arrival)	High	Provides good response time	Can be high	Penalizes long processes	Possible
HRRN	$\max\left(\frac{w+s}{s}\right)$	Nonpreemptive	High	Provides good response time	Can be high	Good balance	No
Feedback	(see text)	Preemptive (at time quantum)	Not emphasized	Not emphasized	Can be high	May favor I/O bound processes	Possible

w = time spent waiting
e = time spent in execution so far
s = total service time required by the process, including e

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Table 9.5 A Comparison of Scheduling Policies

		A	B	C	D	E	
	Process	A	B	C	D	E	
	Arrival Time	0	2	4	6	8	
	Service Time (T_s)	3	6	4	5	2	Mean
FCFS	Finish Time	3	9	13	18	20	
	Turnaround Time (T_r)	3	7	9	12	12	8.60
	T_r/T_s	1.00	1.17	2.25	2.40	6.00	2.56
RR $q = 1$	Finish Time	4	18	17	20	15	
	Turnaround Time (T_r)	4	16	13	14	7	10.80
	T_r/T_s	1.33	2.67	3.25	2.80	3.50	2.71
RR $q = 4$	Finish Time	3	17	11	20	19	
	Turnaround Time (T_r)	3	15	7	14	11	10.00
	T_r/T_s	1.00	2.5	1.75	2.80	5.50	2.71
SPN	Finish Time	3	9	15	20	11	
	Turnaround Time (T_r)	3	7	11	14	3	7.60
	T_r/T_s	1.00	1.17	2.75	2.80	1.50	1.84
SRT	Finish Time	3	15	8	20	10	
	Turnaround Time (T_r)	3	13	4	14	2	7.20
	T_r/T_s	1.00	2.17	1.00	2.80	1.00	1.59
HRRN	Finish Time	3	9	13	20	15	
	Turnaround Time (T_r)	3	7	9	14	7	8.00
	T_r/T_s	1.00	1.17	2.25	2.80	3.5	2.14
FB $q = 1$	Finish Time	4	20	16	19	11	
	Turnaround Time (T_r)	4	18	12	13	3	10.00
	T_r/T_s	1.33	3.00	3.00	2.60	1.5	2.29
FB $q = 2^i$	Finish Time	4	17	18	20	14	
	Turnaround Time (T_r)	4	15	14	14	6	10.60
	T_r/T_s	1.33	2.50	3.50	2.80	3.00	2.63

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Table 9.6 Formulas for Single-Server Queues with Two Priority Categories

Assumptions:
1. Poisson arrival rate.
2. Priority 1 items are serviced before priority 2 items.
3. First-in-first-out dispatching for items of equal priority.
4. No item is interrupted while being served.
5. No items leave the queue (lost calls delayed).

(a) General Formulas

$$\lambda = \lambda_1 + \lambda_2$$
$$\rho_1 = \lambda_1 T_{s1};\ \rho_2 = \lambda_2 T_{s2}$$
$$\rho = \rho_1 + \rho_2$$
$$T_s = \frac{\lambda_1}{\lambda} T_{s1} + \frac{\lambda_2}{\lambda} T_{s2}$$
$$T_r = \frac{\lambda_1}{\lambda} T_{r1} + \frac{\lambda_2}{\lambda} T_{r2}$$

b) No interrupts; exponential service times

$$T_{r1} = T_{s1} + \frac{\rho_1 T_{s1} + \rho_2 T_{s2}}{1 - \rho_1}$$
$$T_{r2} = T_{s2} + \frac{T_{r1} - T_{s1}}{1 - \rho}$$

(c) Preemptive-resume queuing discipline; exponential service times

$$T_{r1} = T_{s1} + \frac{\rho_1 T_{s1}}{1 - \rho_1}$$
$$T_{r2} = T_{s2} + \frac{1}{1 - \rho_1}\left(\rho_1 T_{s2} + \frac{\rho T_s}{1 - \rho}\right)$$

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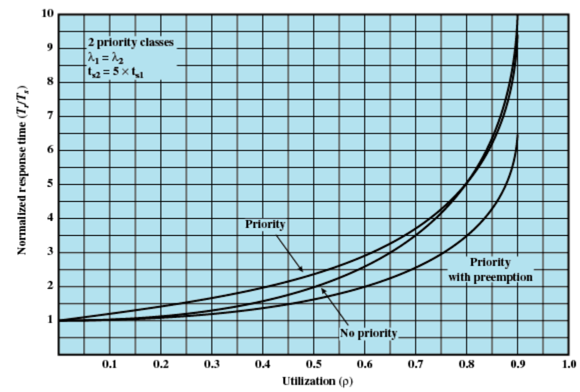

Figure 9.11 Overall Normalized Response Time

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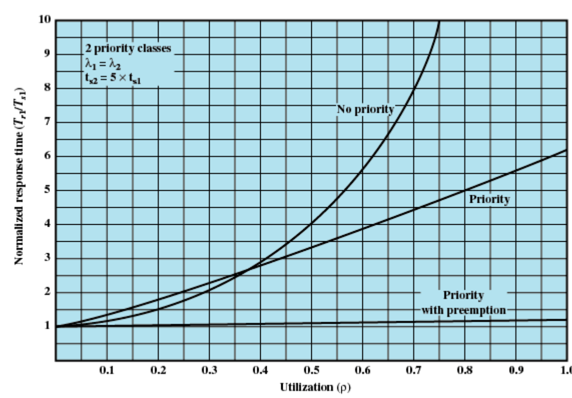

Figure 9.12 Normalized Response Time for Shorter Processes

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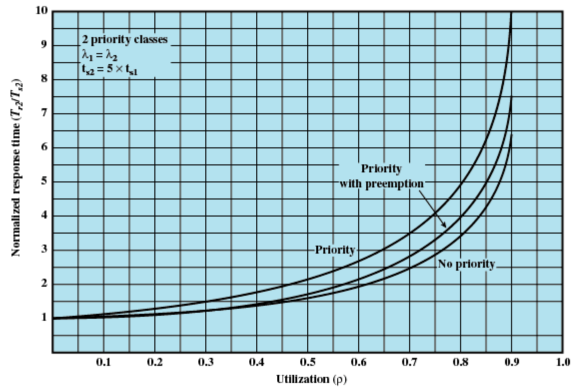

Figure 9.13 Normalized Response Time for Longer Processes

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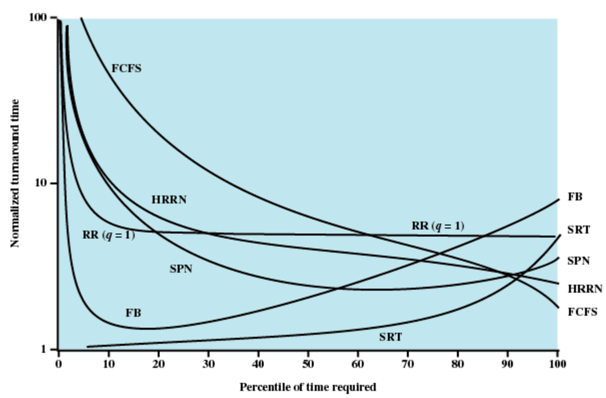

Figure 9.14 Simulation Results for Normalized Turnaround Time

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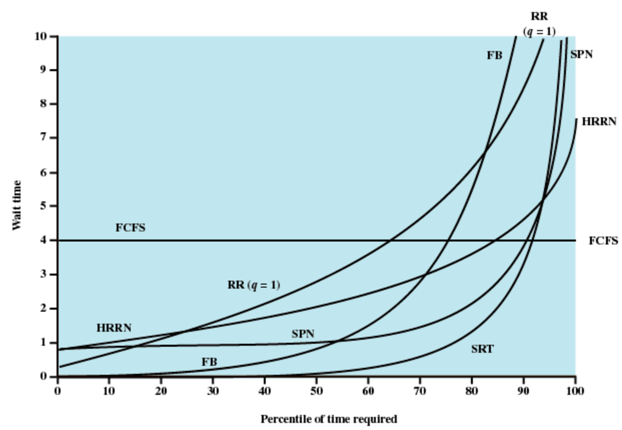

Figure 9.15 Simulation Results for Waiting Time

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Fair-Share Scheduling

- User's application runs as a collection of processes (threads)
- User is concerned about the performance of the application
- Need to make scheduling decisions based on process sets

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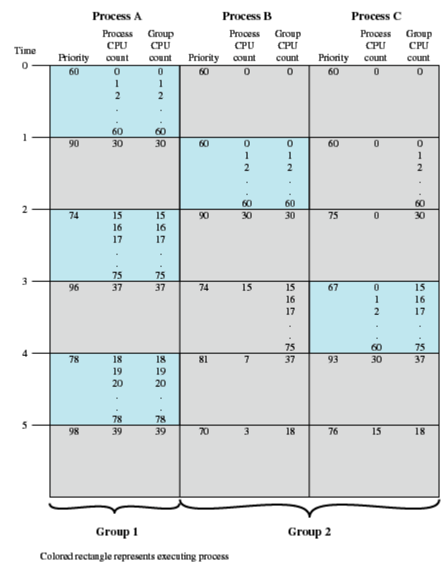

Figure 9.16 Example of Fair Share SchedulerÑThree Processes, Two Groups

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Traditional UNIX Scheduling

- Multilevel feedback using round robin within each of the priority queues
- If a running process does not block or complete within 1 second, it is preempted
- Priorities are recomputed once per second
- Base priority divides all processes into fixed bands of priority levels

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Bands

- Decreasing order of priority
  - Swapper
  - Block I/O device control
  - File manipulation
  - Character I/O device control
  - User processes

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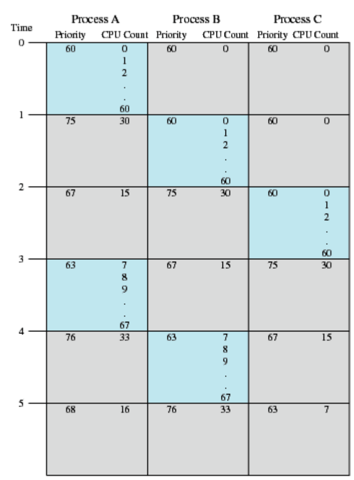

Colored rectangle represents executing process

Figure 9.17 Example of Traditional UNIX Process Scheduling

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