Uniprocessor Scheduling

types of scheduling in OS

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

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

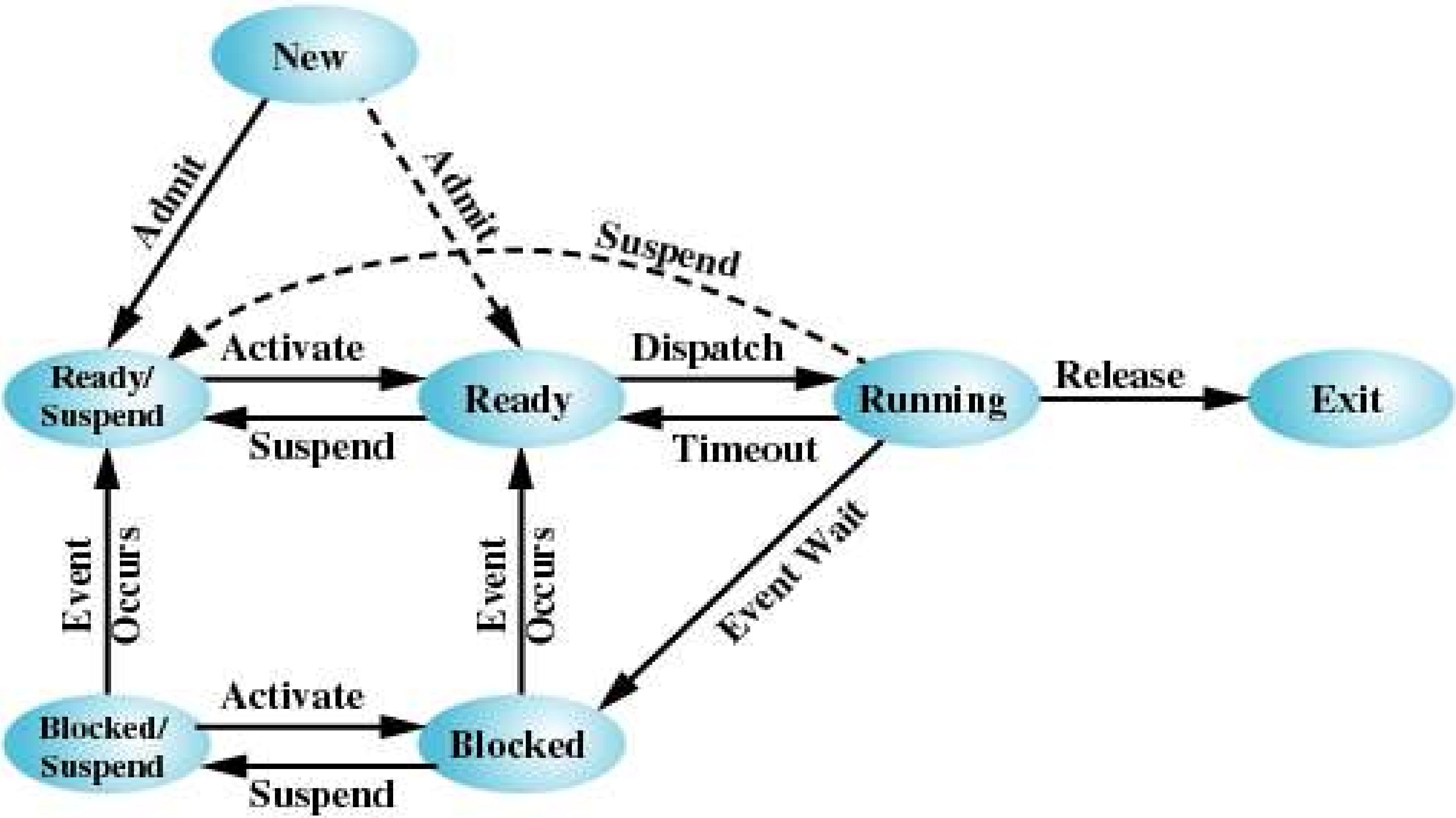
Medium-Term Scheduling

- i.e. swapping
- Based on the need to manage the degree of multiprogramming

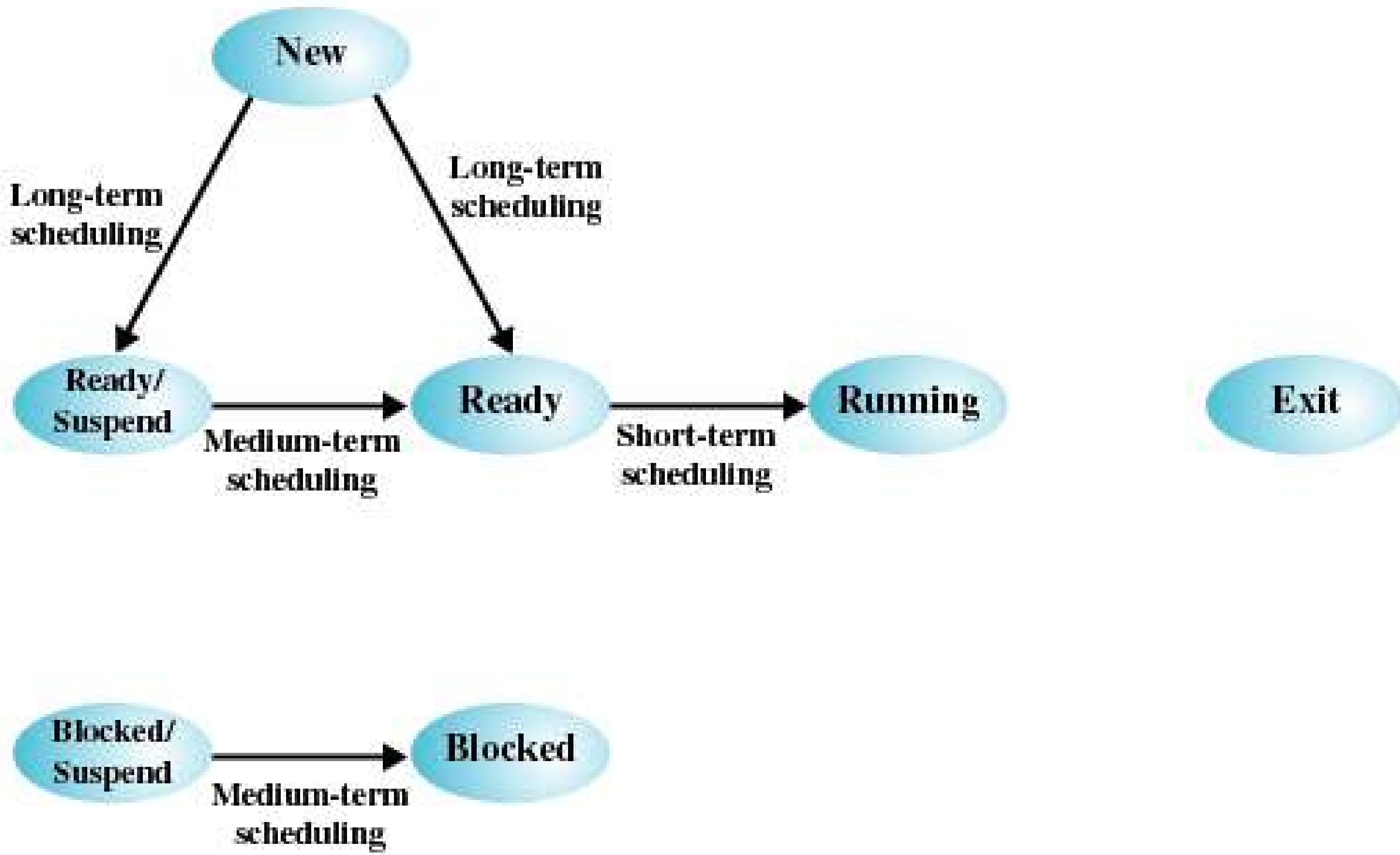
Short-Term (cpu) Scheduling

- a cpu scheduling policy decides for each cpu...
  - which process should be executed
  - how long it will be executed
- implemented in the dispatcher, a.k.a. scheduler
- the scheduler executes very frequently
  - Invoked when an event occurs
    - Timer interrupts
    - I/O interrupts
    - traps
    - Operating system calls

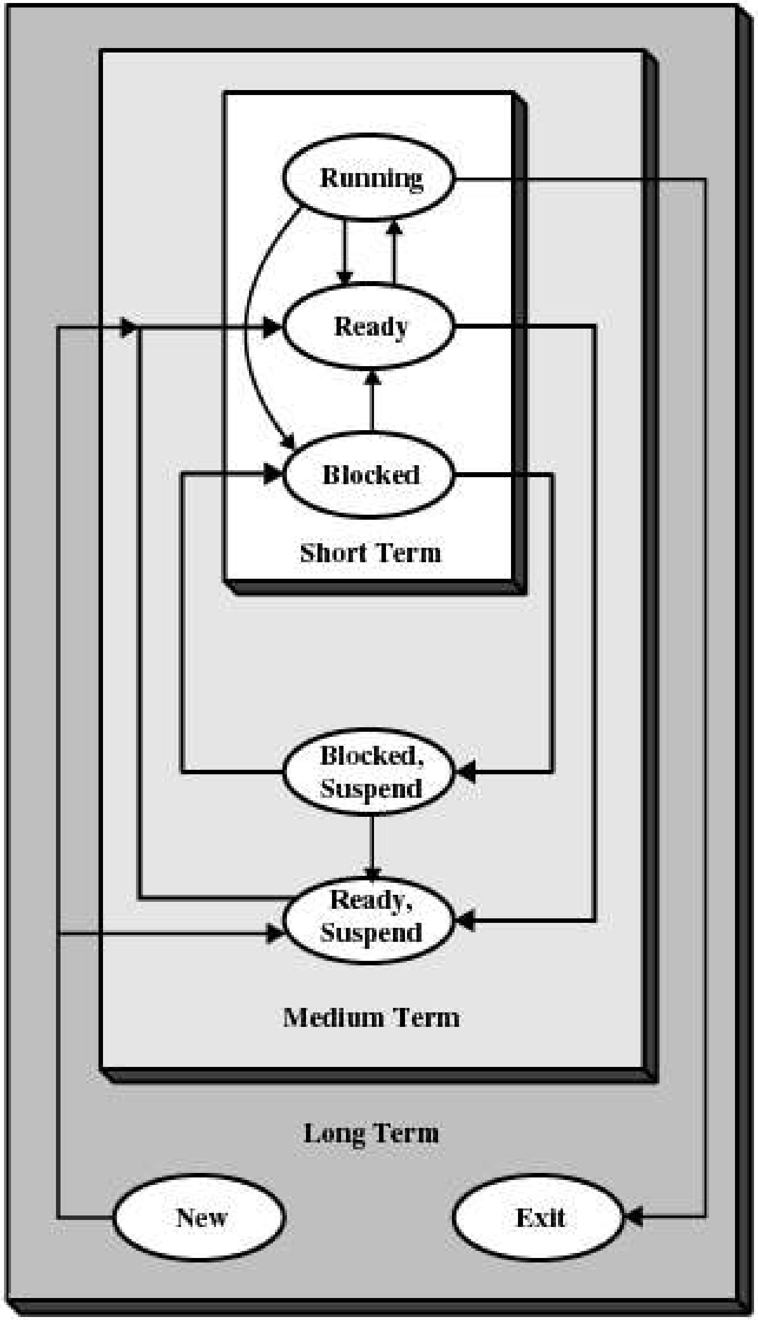
process states



scheduling and process state transitions

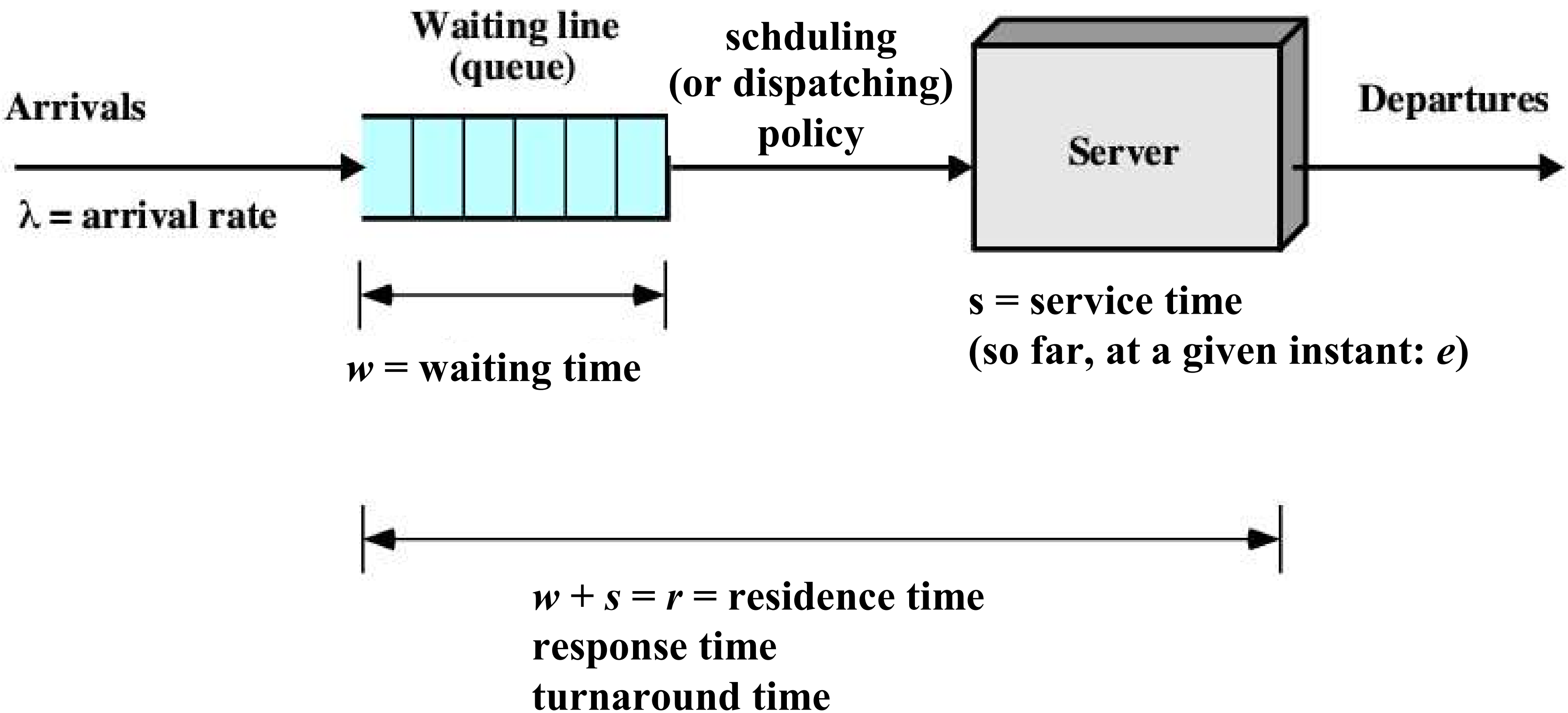


levels of scheduling



short term cpu scheduling

queue



$$\lambda \leqslant \frac{1}{s}$$ (statistically)

Optimality Criteria

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

- other
  - predictability
  - fairness
  - ecc.

Optimality Criteria

- User-oriented
  - Response Time
    - Elapsed time from submission to begin of the service.
  - Normalized Response Time w.r.t. service time, that is $(w+s)/s$
- System-oriented
  - Effective and efficient utilization of the processor

optimality 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.

scheduling criteria

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.

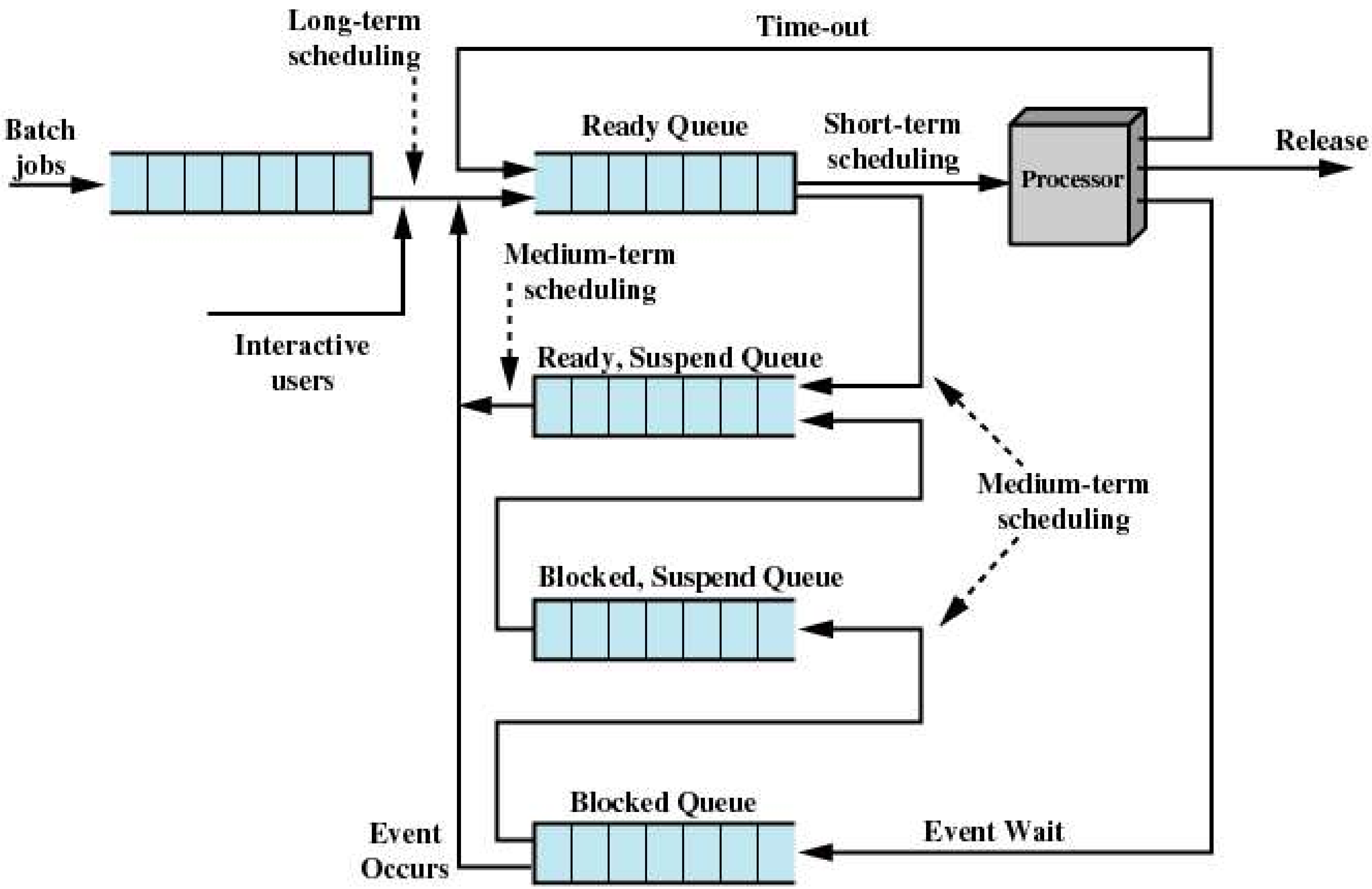
System Oriented, Other

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.

scheduling queuing diagram



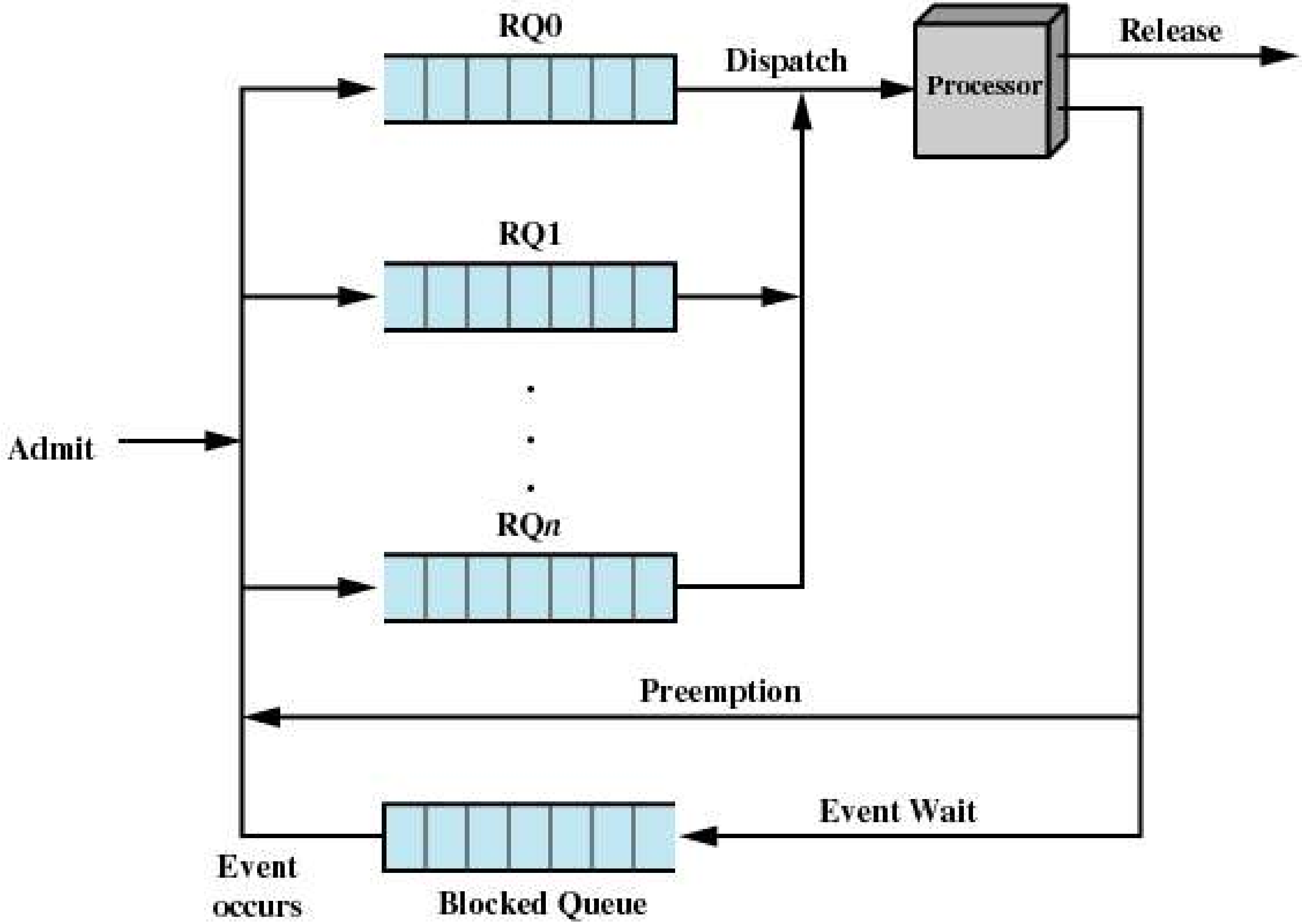
Priorities

- a priority is assigned to each process
- a ready process queue for each priority
- Scheduler will always choose a process of higher priority over one of lower priority
- Lower-priority may suffer starvation
  - Allow a process to change its priority based on its age or execution history

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

priority queuing and preemption



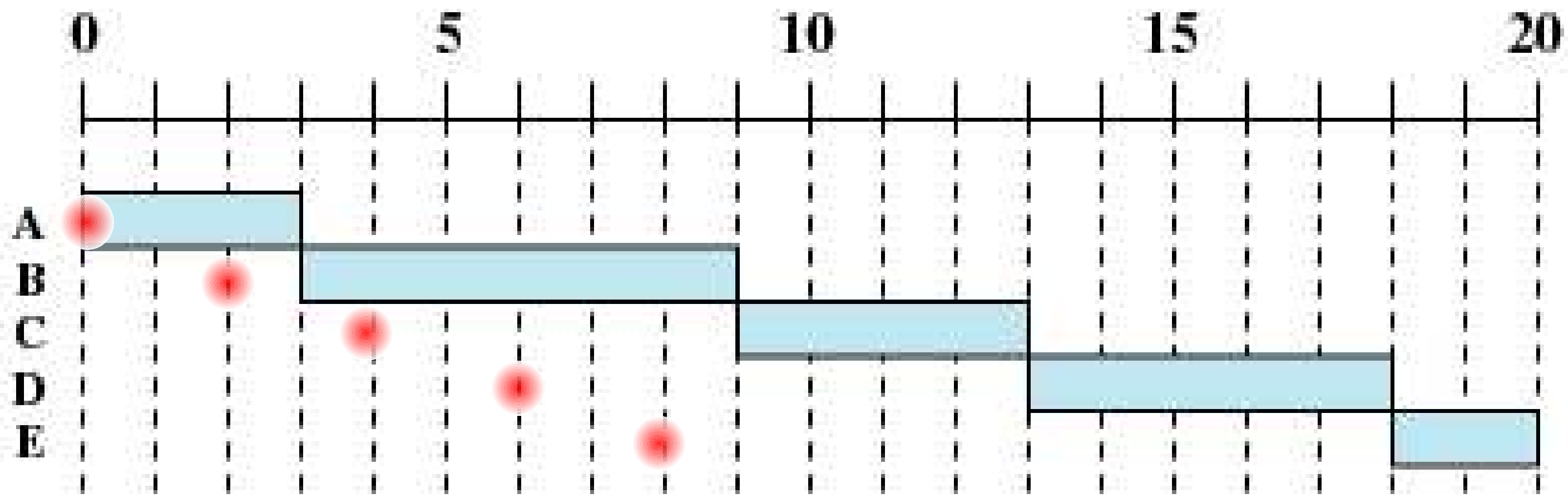
Process Scheduling Example

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

- arrival time: when the process enter the ready queue
- service time: the process virtual time elapsed till the next blocking operation

First-Come-First-Served (FCFS)

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



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

First-Come-First-Served (FCFS)

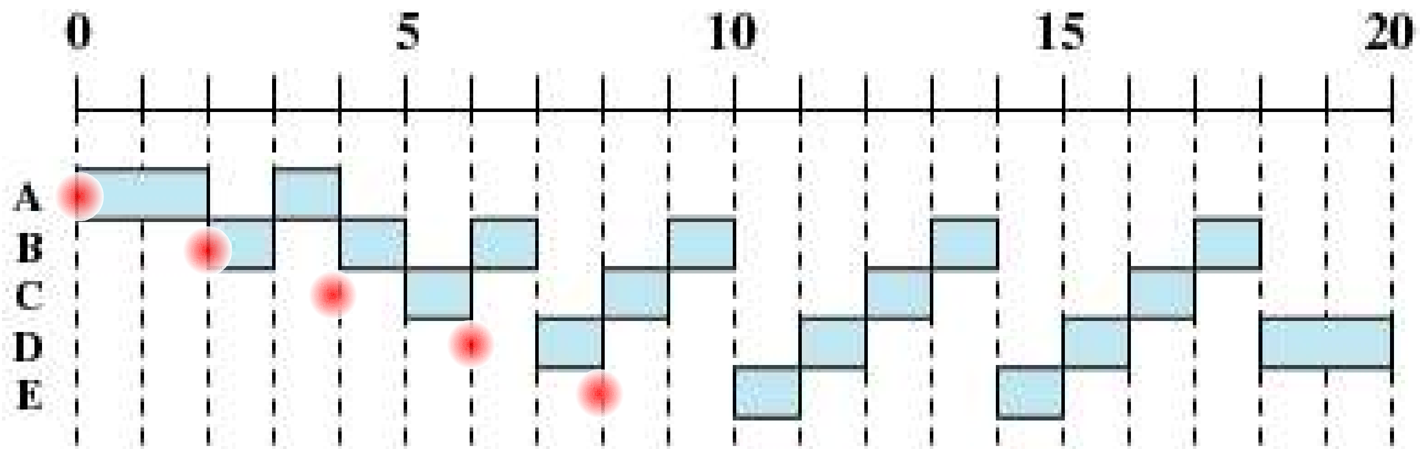
- A short process may have to wait a very long time before it can execute
- Favors CPU-bound processes
  - I/O processes have to wait until CPU-bound process completes

First-Come-First-Served (FCFS)

Processo	Tempo di arrivo	Tempo di servizio (T_s)	Tempo di inizio	Tempo di fine	Tempo di turnaround (T_r)	T_r / T_s
A	0	1	0	1	1	1
B	1	100	1	101	100	1
C	2	1	101	102	100	100
D	3	100	102	202	199	1.99
Media					100	26

Round-Robin (RR), *q*=1

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

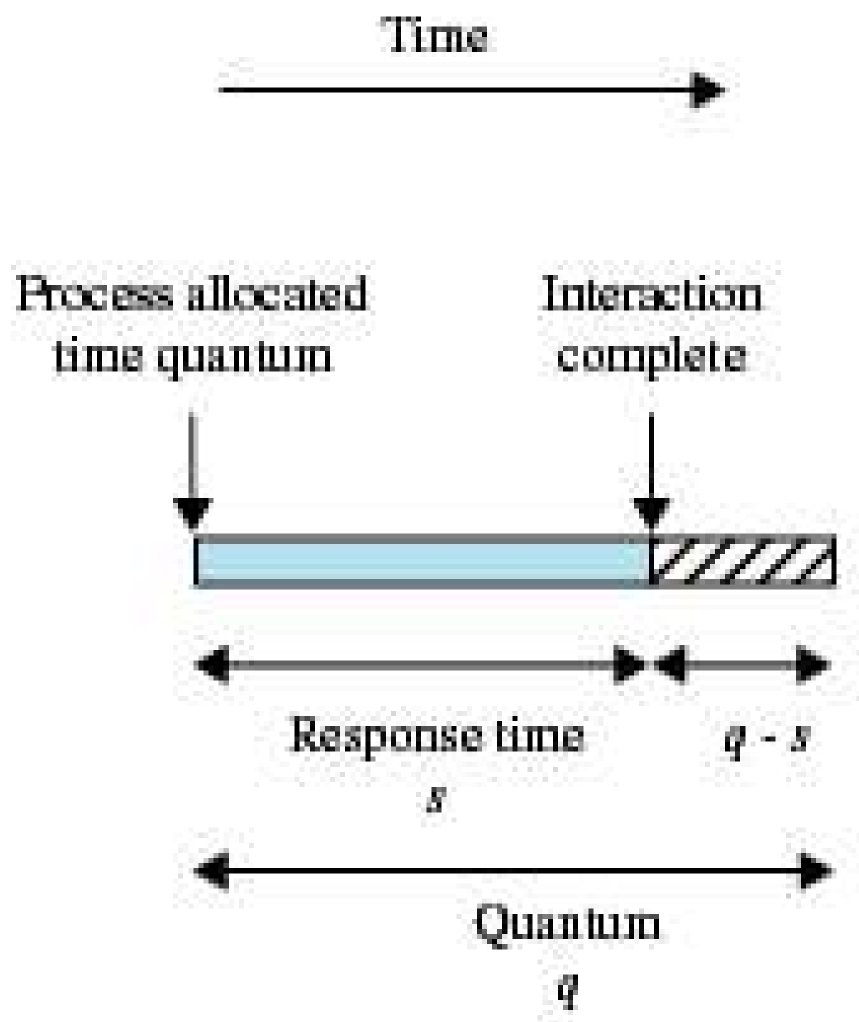


- Uses **preemption** based on a clock
- An amount of time (**quantum** *q*) is determined that allows each process to use the processor for that length of time

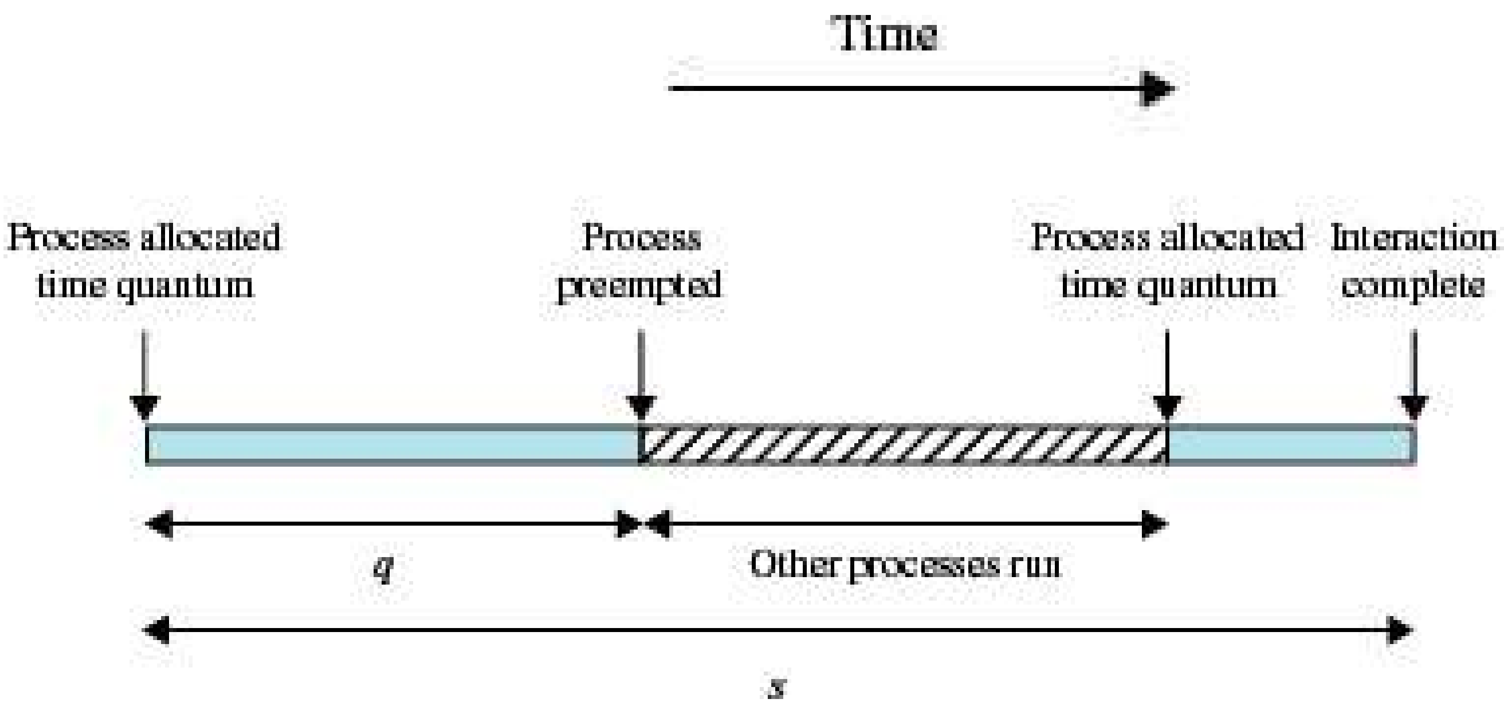
Round-Robin

- Clock interrupt is generated at periodic intervals
- When an interrupt occurs, the currently running process is placed in the read queue (preempted)
  - Next ready job is selected
- a.k.a. time slicing

effect of size of preemption time quantum



effect of size of preemption time quantum



(b) Time quantum less than typical interaction

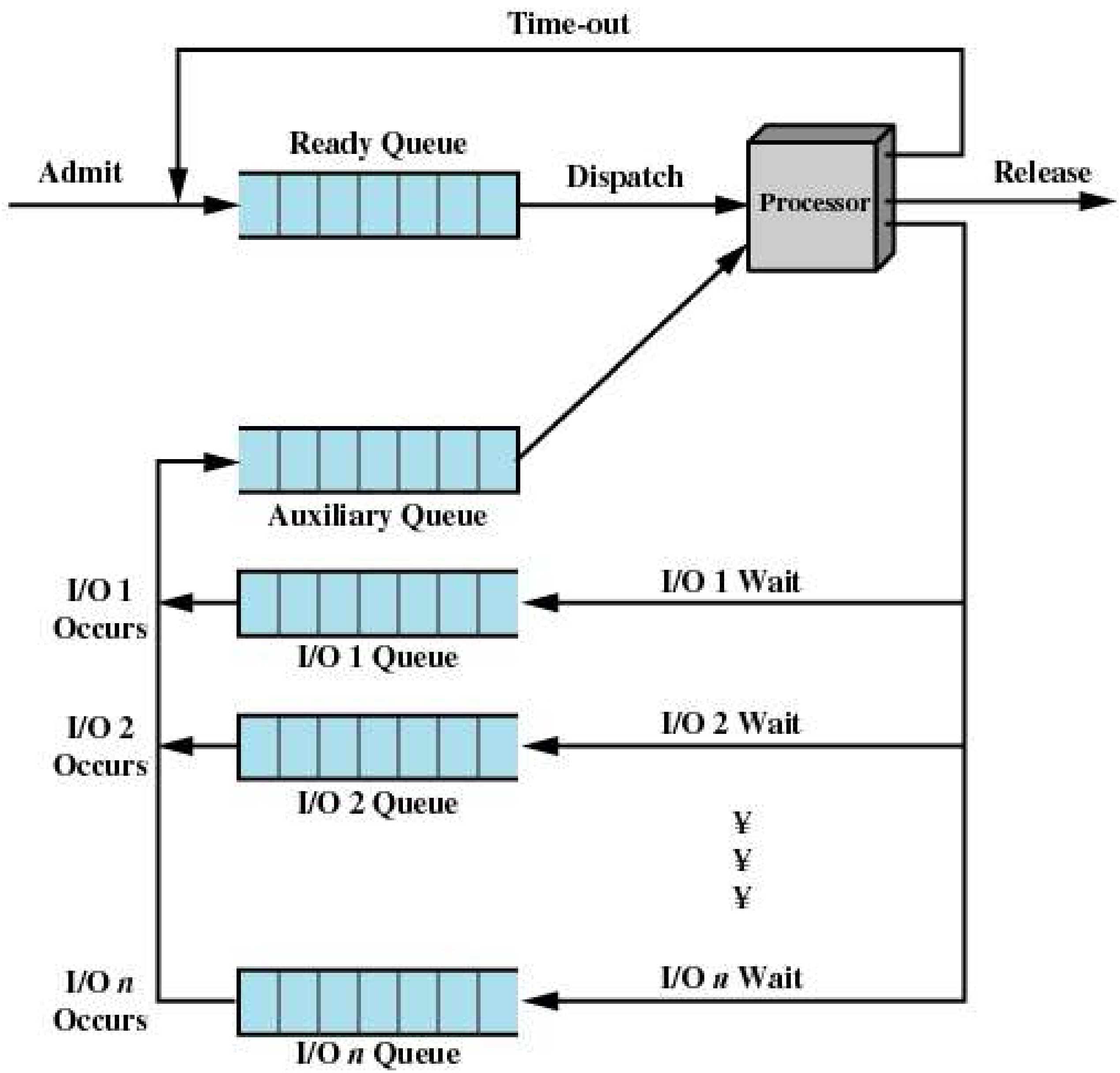
unfairness of RR

- I/O-bound processes usually release cpu before expiration of their quantum
- cpu-bound processes run for the whole quantum

- RR prefers cpu-bound processes

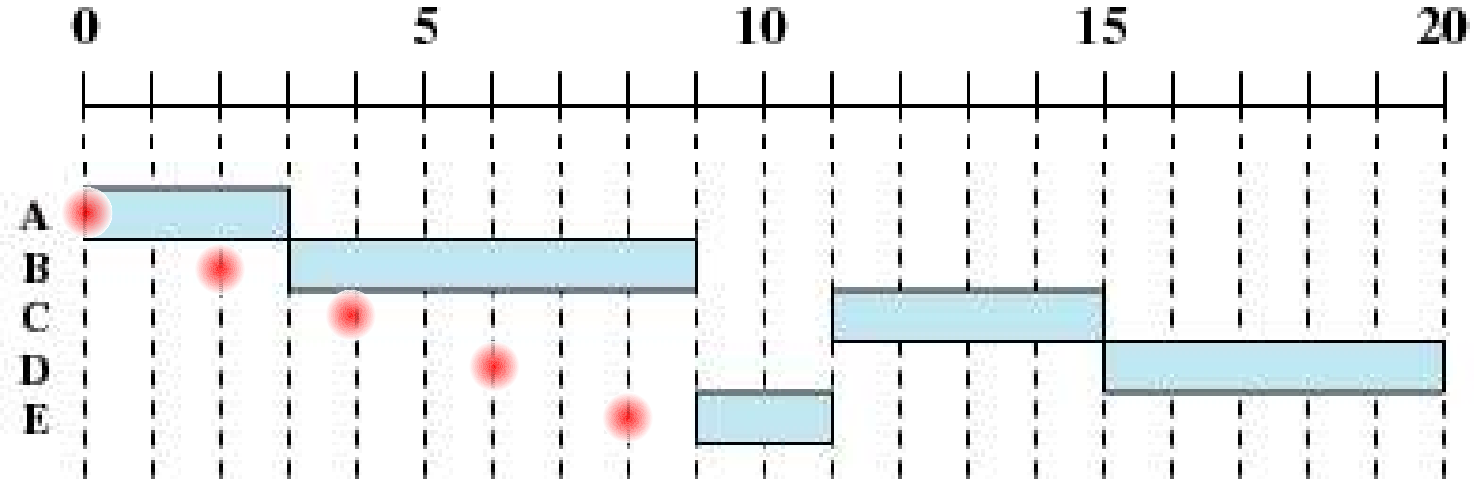
virtual round robin

- aux queue is preferred over ready queue
- processes from aux queue run for their remaining quantum fraction



Shortest Process Next (SPN, SJF)

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



- Nonpreemptive policy, optimal w.r.t. min total waiting time
- need to know future! approximated.
- expected processing time to the next blocking i/o operation
- process with shortest expected processing time is selected next

Shortest Process Next

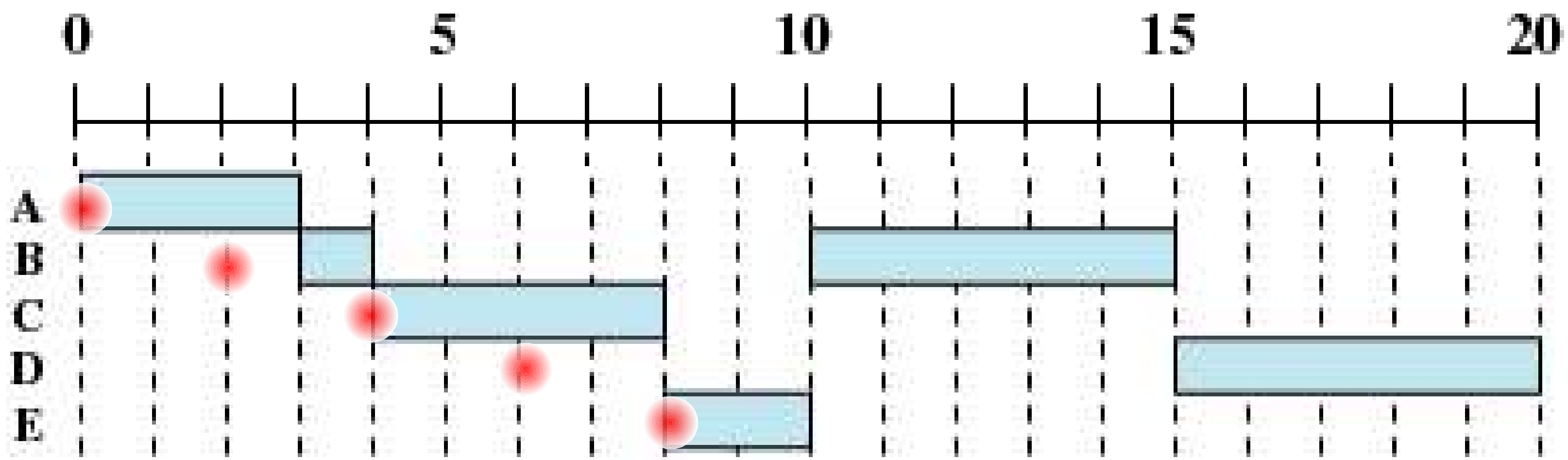
- Predictability of longer processes is reduced
- Possibility of starvation for longer processes
- exstimation of time length of the next cpu-bust may be done by exponential averaging

$$S_{n+1} = \alpha T_n + (1-\alpha) S_n$$

$$\alpha \in (0,1]$$

Shortest Remaining Time (SRT)

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



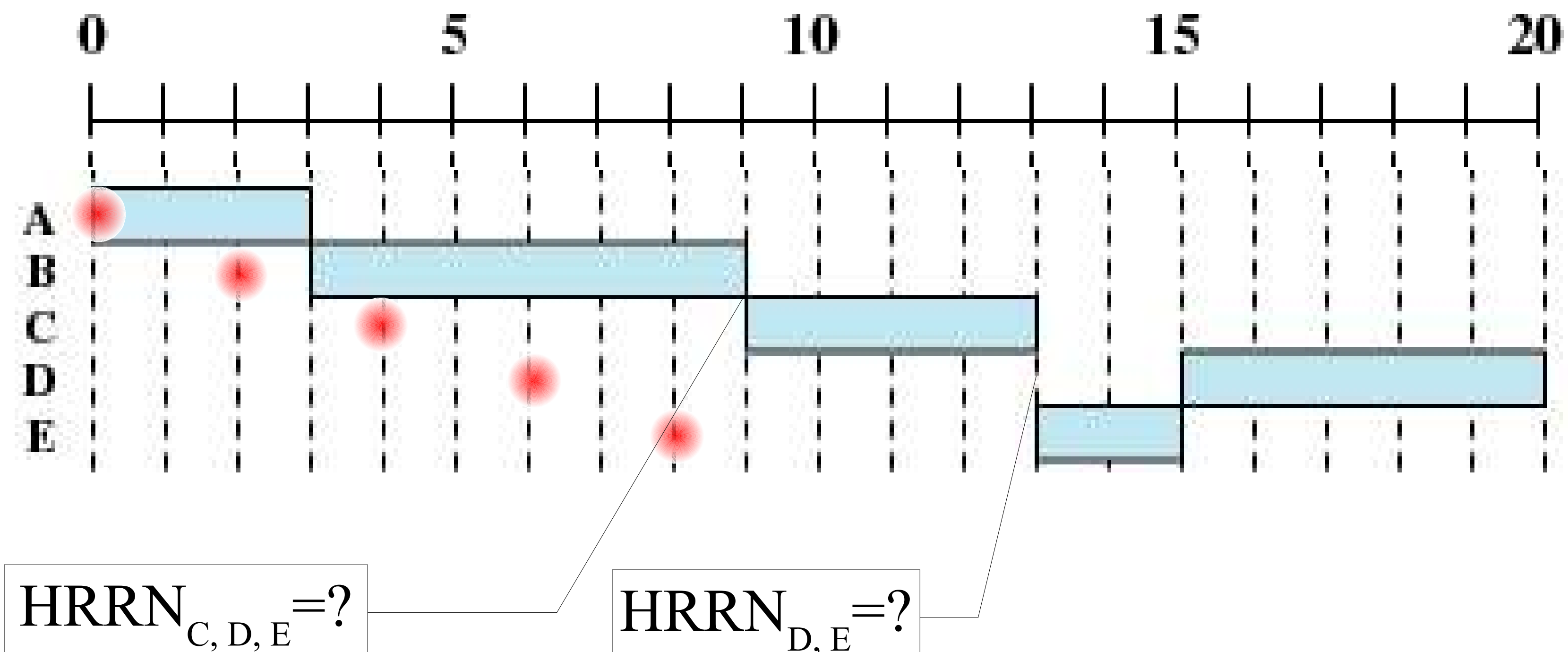
- Preemptive version of shortest process next policy
- Must estimate processing time

Highest Response Ratio Next (HRRN)

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

- non preemptive
- choose next process with the greatest ratio

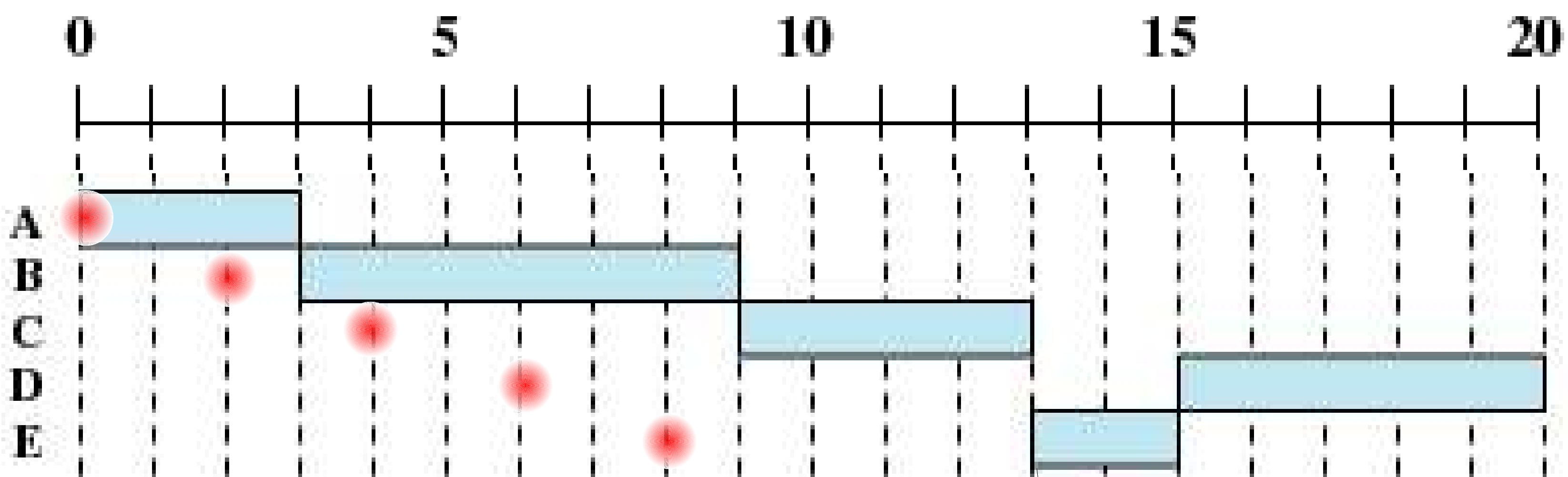
$$\frac{\textbf{time spent waiting + expected service time}}{\textbf{expected service time}} = \frac{w+s}{s}$$



Highest Response Ratio Next (HRRN)

$$\frac{w+s}{s}$$

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



$HRRN_C=(5+4)/4=2.25$

$HRRN_D=(3+5)/5=1.6$

$HRRN_E=(1+2)/2=1.5$

$HRRN_D=(5+2)/2=3.5$

$HRRN_E=(7+5)/2=6$

a first comparison

- FCFS
  - penalize i/o-bound processes
- RR
  - penalize i/o-bound processes
- VRR
  - fair, do not emphasize response time of i/o-bound processes
- SPN, SRT, HRRN
  - need service time prediction

feedback

- does not need service time estimation
- preemptive as in RR (q=1 or $q=2^i$)
- demotes processes at each expired time quantum into lower priority queues

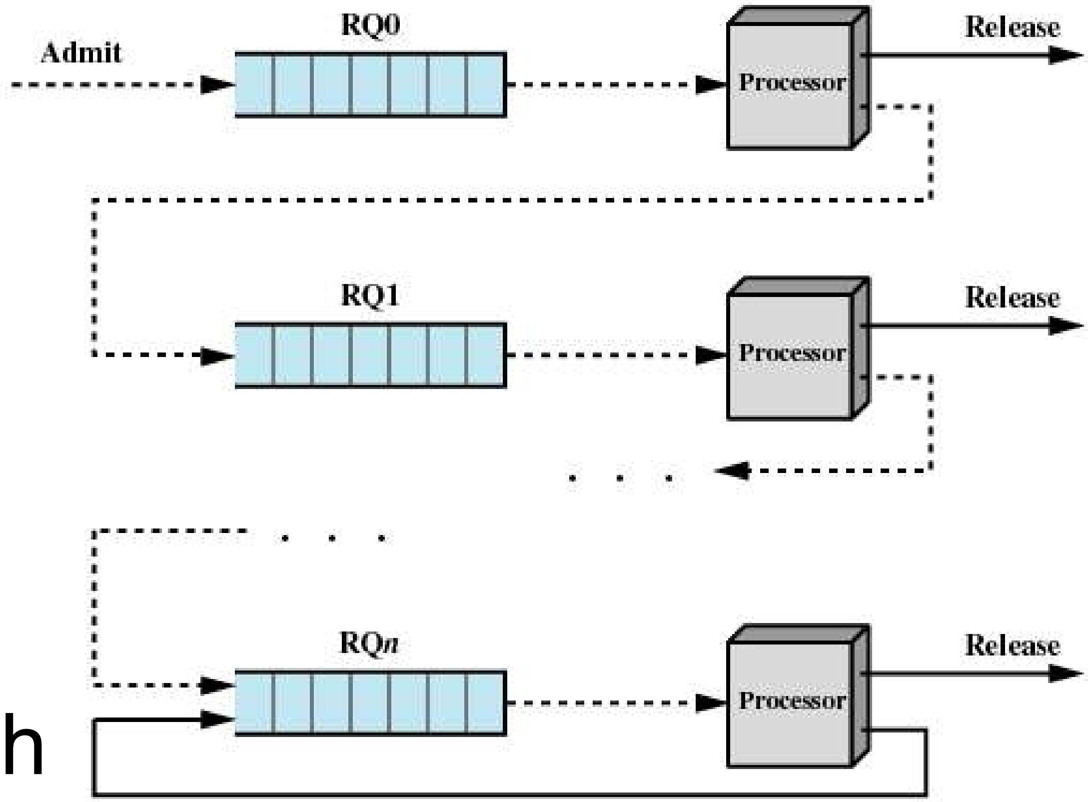


Figure 9.10 Feedback Scheduling

feedback: varianti

- un processo scala di priorita'...
  - sempre quando scade il suo quanto di tempo

  oppure
  - quando scade il quanto e c'e` una altro processo nella sua coda

  oppure
  - quando scade il quanto e c'e` almeno una altro processo nel sistema (Stallings)

Feedback

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

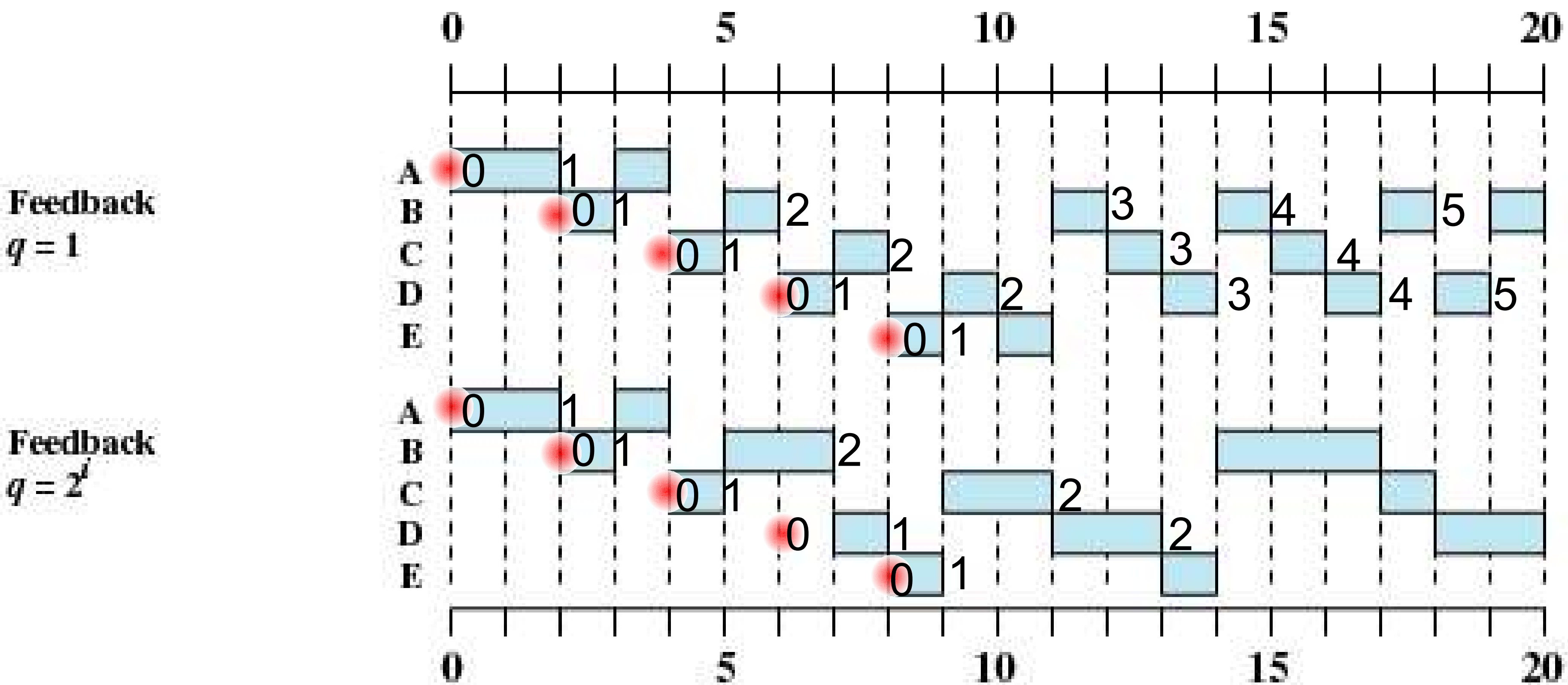


Table 9.3 Characteristics of Various Scheduling Policies

	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

simulation results