Operating System

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Chapter 09

Scheduling

调度

Learning Objectives

- **Explain the differences among long-, medium-, and short-term scheduling**
- **Assess the performance of different scheduling policies**

Outline

- **Types of Processor Scheduling**
  - Long-Term Scheduling
  - Medium-Term Scheduling
  - Short-Term Scheduling
- **Scheduling Algorithms**
  - Short-Term Scheduling Criteria
  - The Use of Priorities
  - Alternative Scheduling Policies

Processor Scheduling

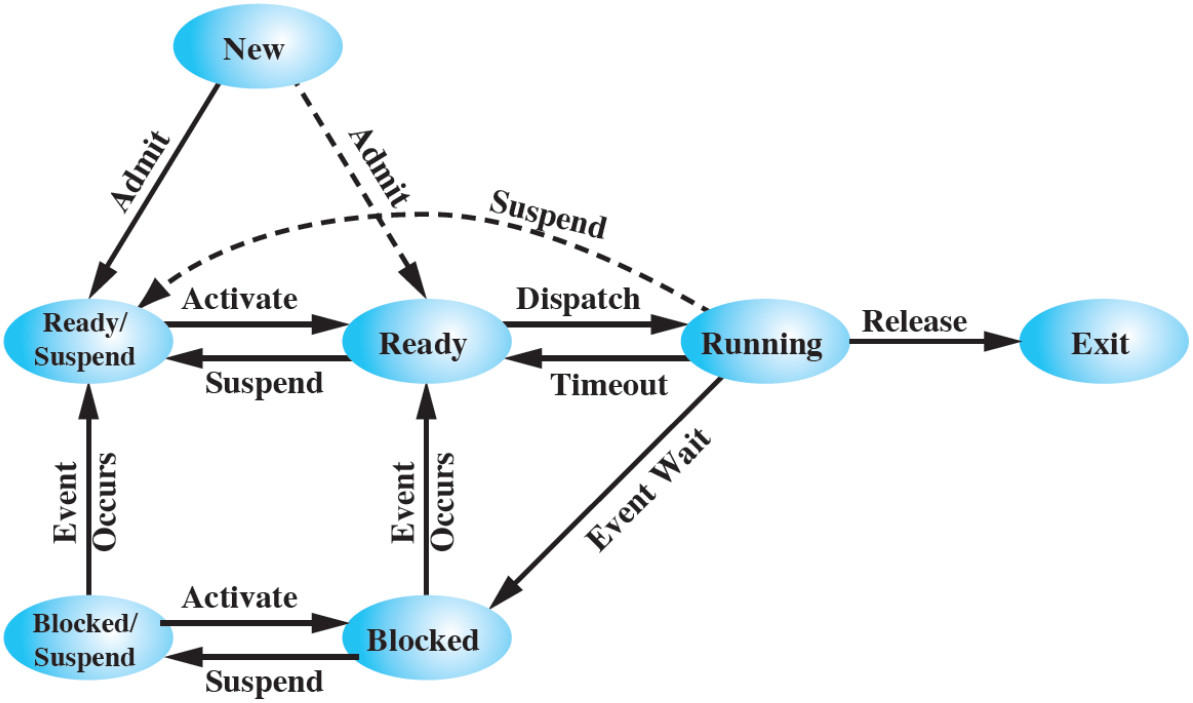
- **Aim is to assign processes to be executed by the processor in a way that meets system objectives**

- **system objectives**
  - response time
  - throughput
  - processor efficiency

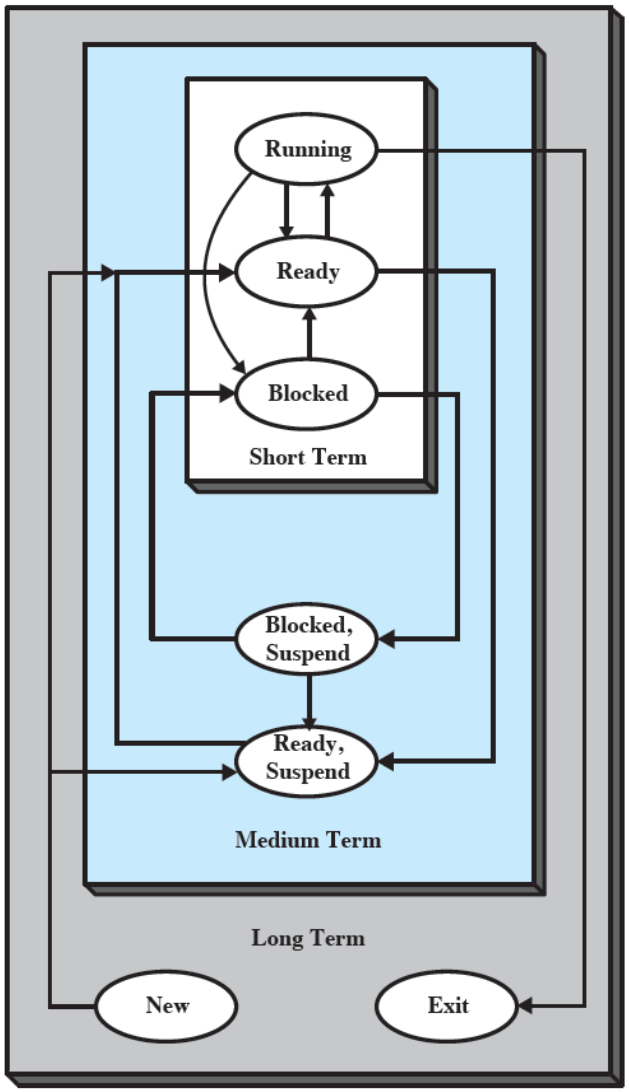
Types of Scheduling

- **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

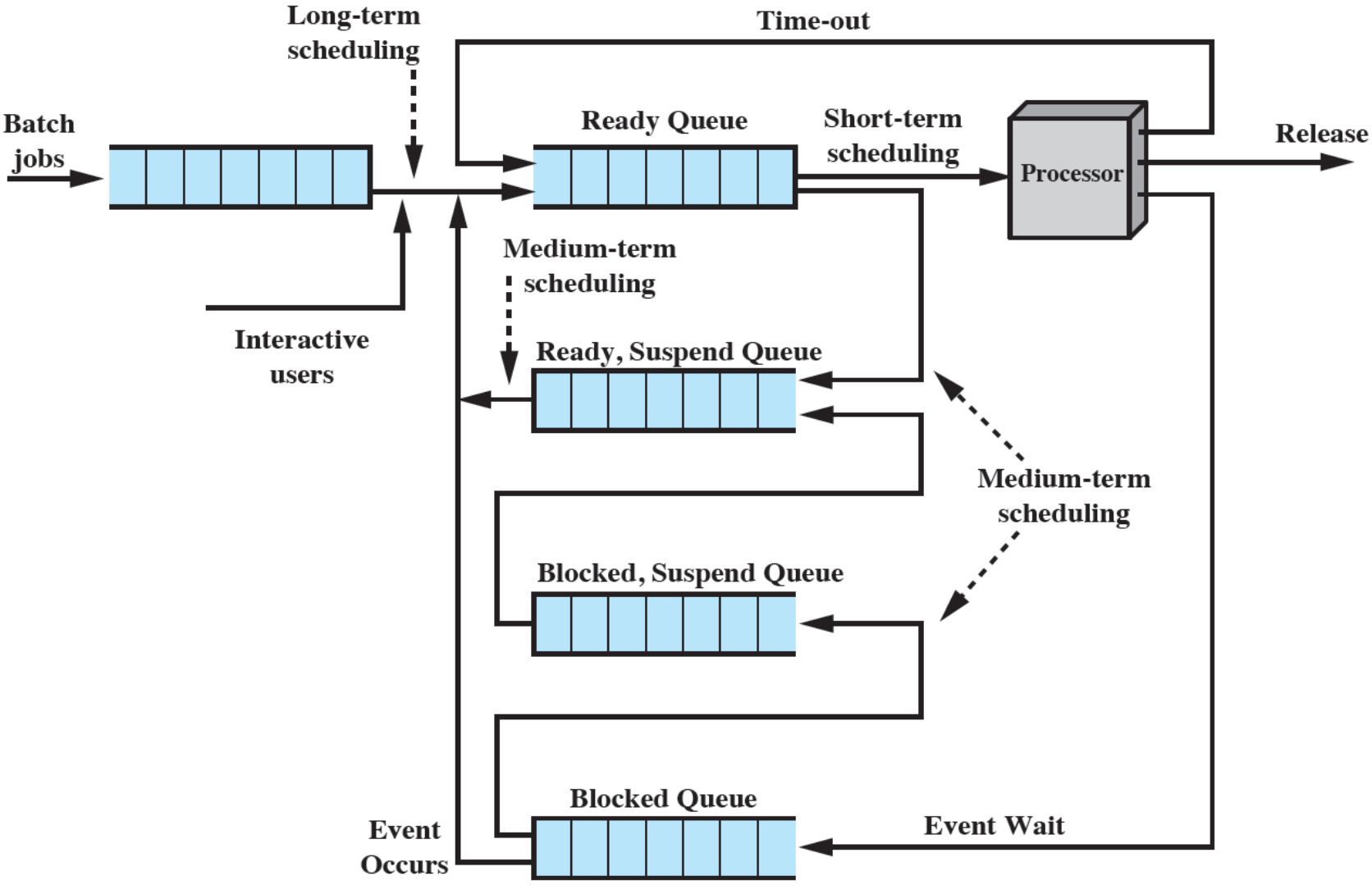
Nesting of Scheduling Functions



(b) With Two Suspend States

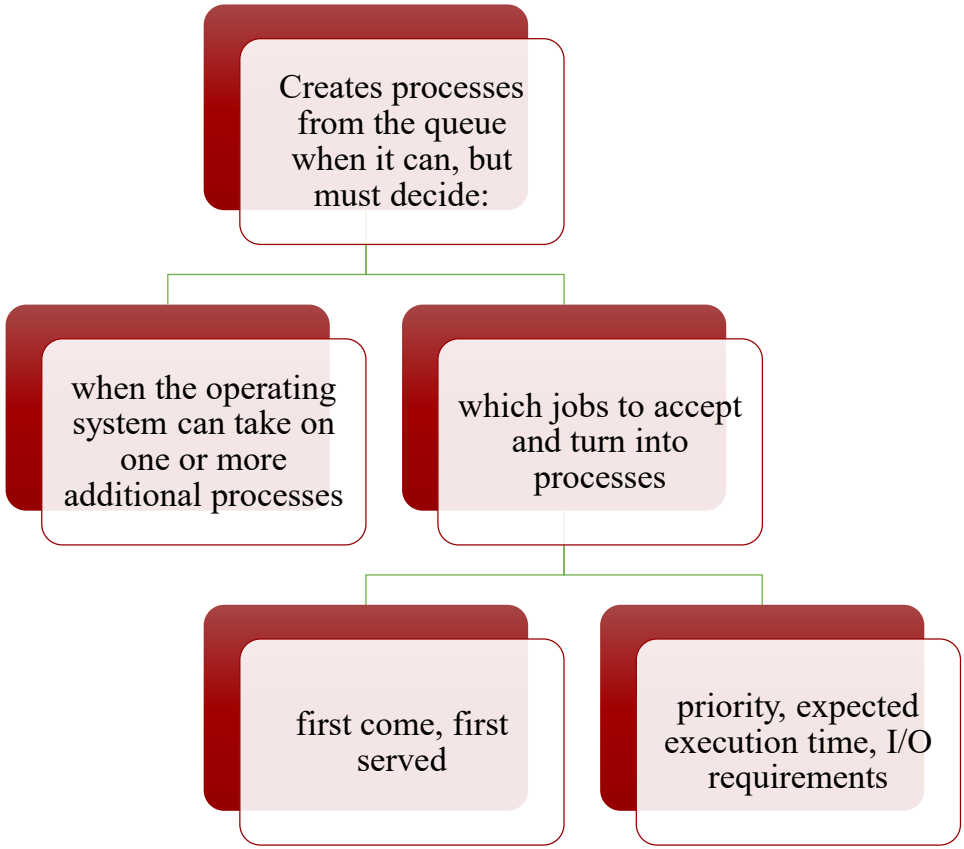


Queuing Diagram for Scheduling



Long-Term Scheduler

- **Determines which programs are admitted to the system for processing**
- **Controls the degree of multiprogramming**
  - the more processes that are created, the smaller the percentage of time that each process can be executed
  - may limit to provide satisfactory service to the current set of processes



Medium-Term Scheduling

- **Part of the swapping function**
- **Swapping-in decisions are based on the need to manage the degree of multiprogramming**
  - considers the memory requirements of the swapped-out processes

Short-Term Scheduling

- Known as the dispatcher, Executes most frequently
- Makes the fine-grained decision of which process to execute next
- Invoked when an event occurs that may lead to the blocking of the current process or that may provide an opportunity to preempt a currently running process in favor of another
  - Clock interrupts
  - I/O interrupts
  - Operating system calls
  - Signals (e.g., semaphores)

Short Term Scheduling Criteria

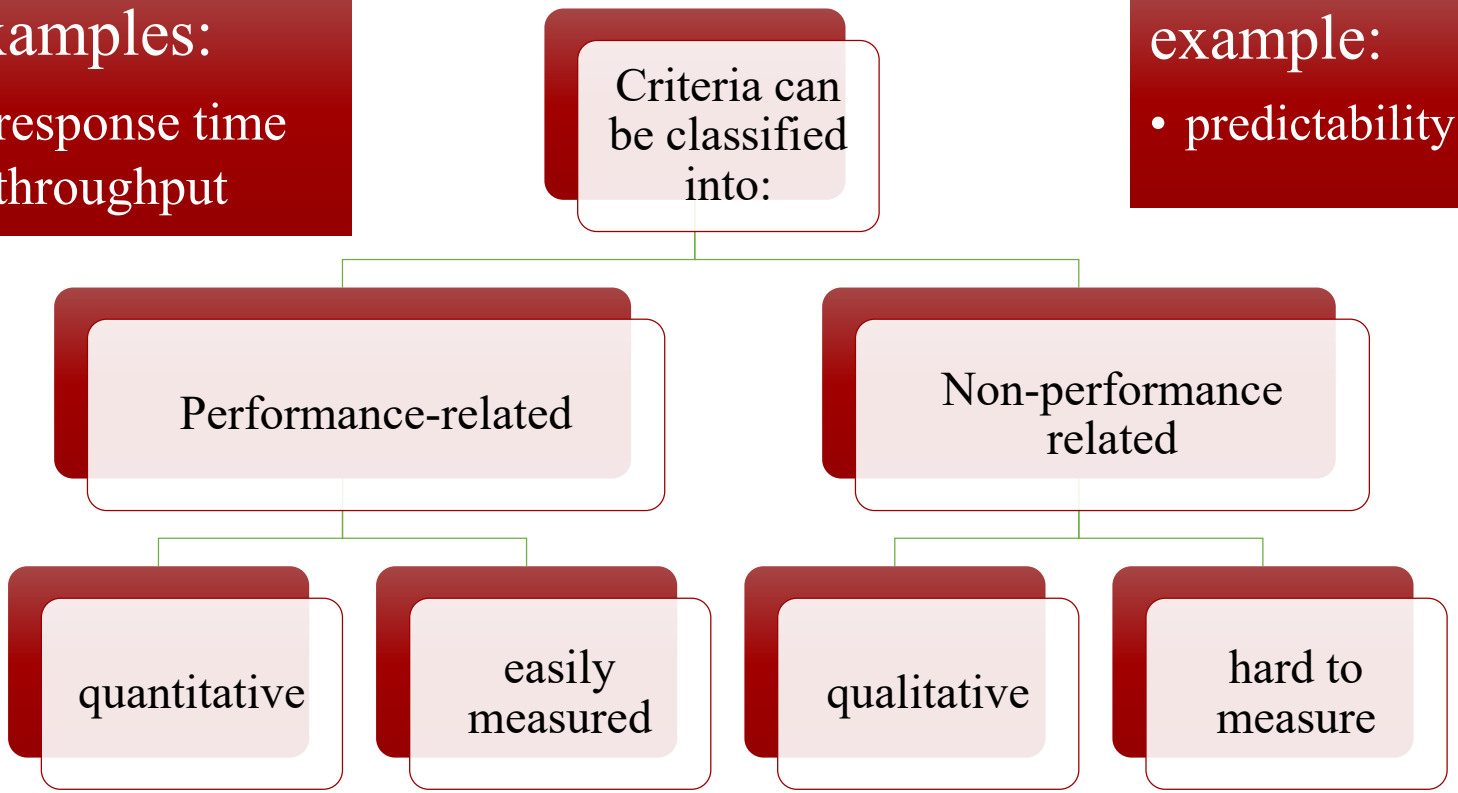
- **Main objective is to allocate processor time to optimize certain aspects of system behavior**
- **A set of criteria is needed to evaluate the scheduling policy**

- **User-oriented criteria**
  - relate to the behavior of the system as perceived by the individual user or process (such as response time in an interactive system)
  - important on virtually all systems

- **System-oriented criteria**
  - focus in on effective and efficient utilization of the processor (rate at which processes are completed)
  - generally of minor importance on single-user systems

Short-Term Scheduling Criteria: Performance

examples:
- response time
- throughput



example:
- predictability

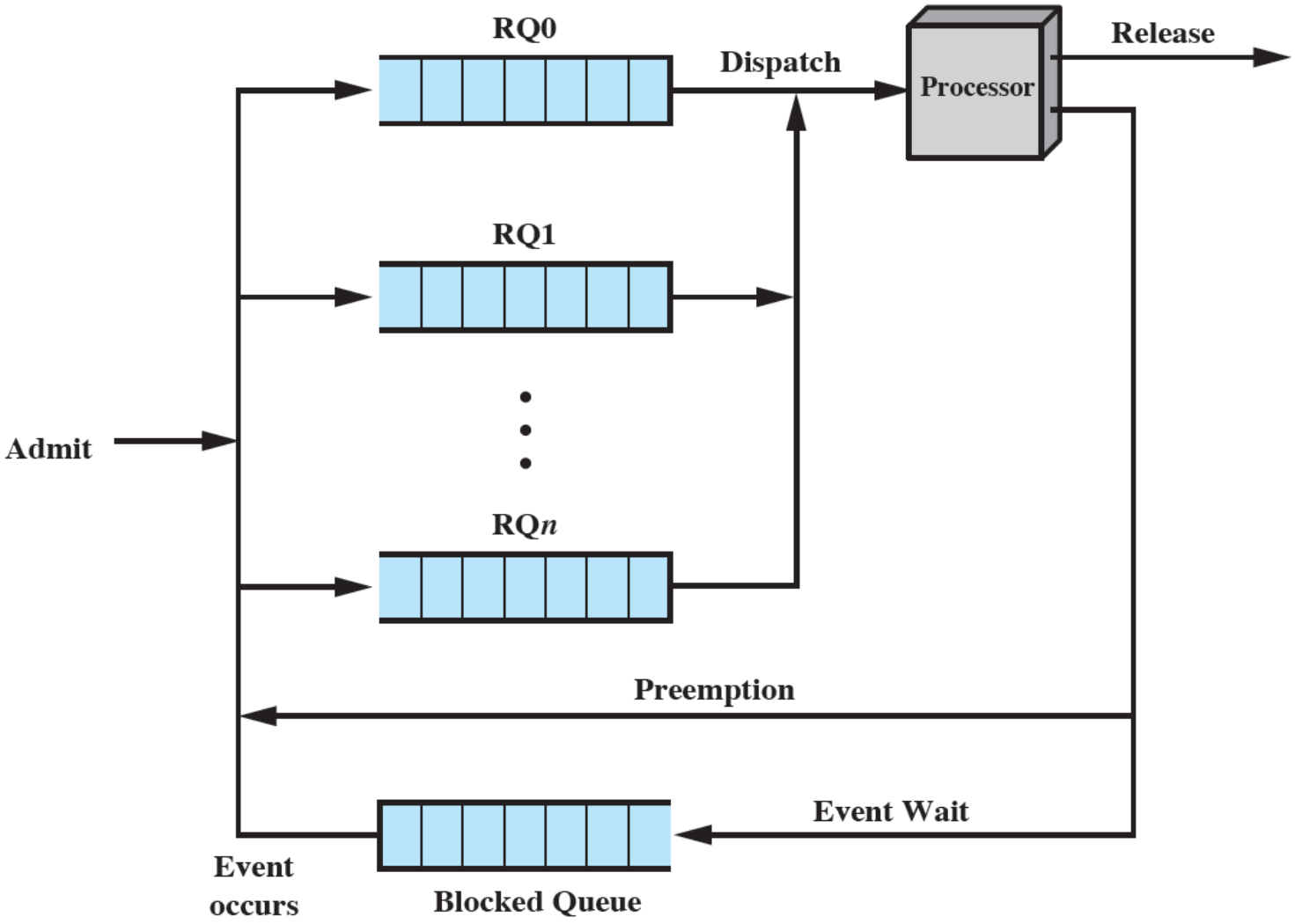
Scheduling Criteria

- **User Oriented**
  - **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
  - **Deadlines**
    - When process completion deadlines can be specified, the scheduling discipline should subordinate other goals to that of maximizing the percentage of deadlines met
  - **Response time**
    - For an interactive process, this is the time from the submission of a request until the response begins to be received.
    - The scheduling discipline should attempt to achieve low response time and to maximize the number of interactive users receiving acceptable response time.
  - **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

Scheduling Criteria

- **System Oriented**
  - **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.
  - **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.
  - **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

Priority Queueing



Characteristics of Various Scheduling Policies

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

Selection Function

- **Determines which process, among ready processes, is selected next for execution**
- **May be based on priority, resource requirements, or the execution characteristics of the process**
- **If based on execution characteristics then important quantities are:**
  - w = time spent in system so far, waiting
  - e = time spent in execution so far
  - s = total service time required by the process, including e; generally, this quantity must be estimated or supplied by the user

Decision Mode

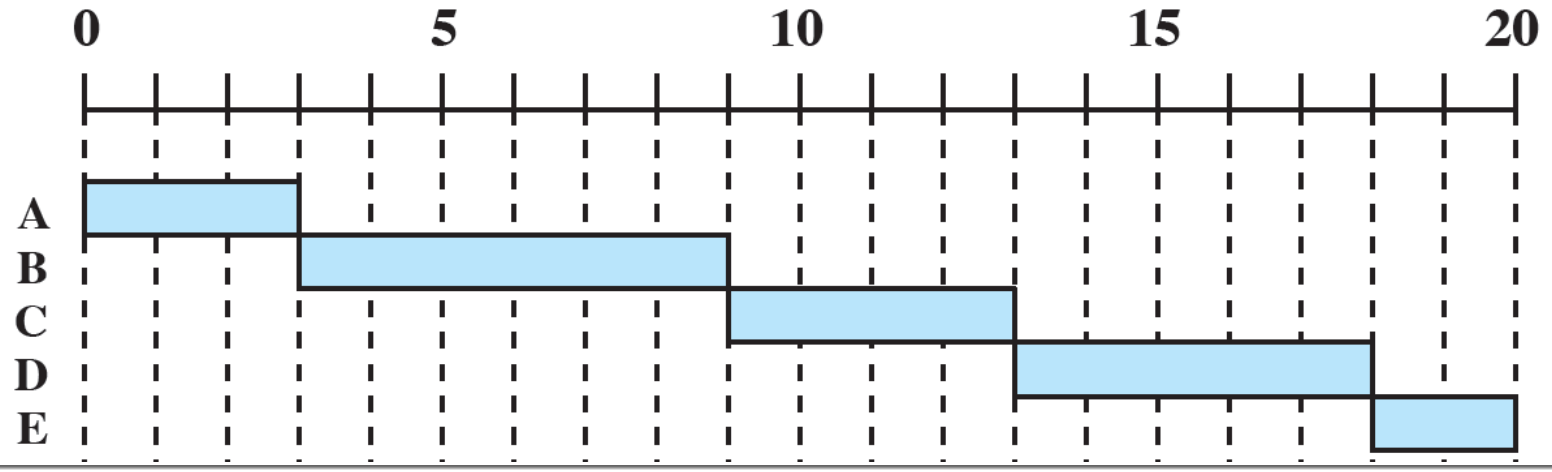
- **Specifies the instants in time at which the selection function is exercised**
- **Two categories:**
  - Nonpreemptive
    - once a process is in the running state, it will continue until it terminates or blocks itself for I/O
  - Preemptive
    - currently running process may be interrupted and moved to ready state by the OS
    - preemption may occur when new process arrives, on an interrupt, or periodically

Process Scheduling Example

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

First-Come-First-Served (FCFS)

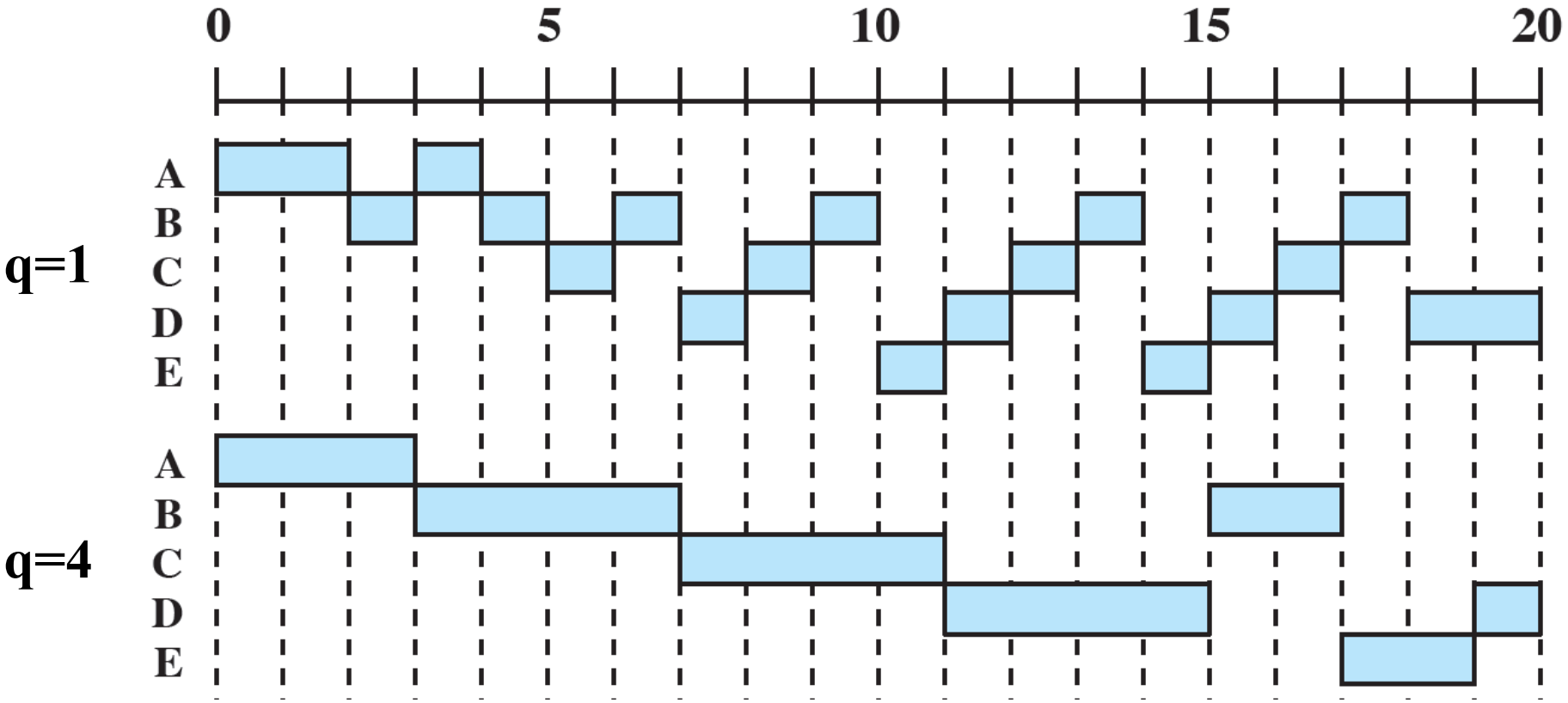
- Also known as first-in-first-out (FIFO) or a strict queuing scheme
- When the current process ceases to execute, the longest process in the Ready queue is selected
- Performs much better for long processes than short ones
- Tends to favor processor-bound processes over I/O-bound processes



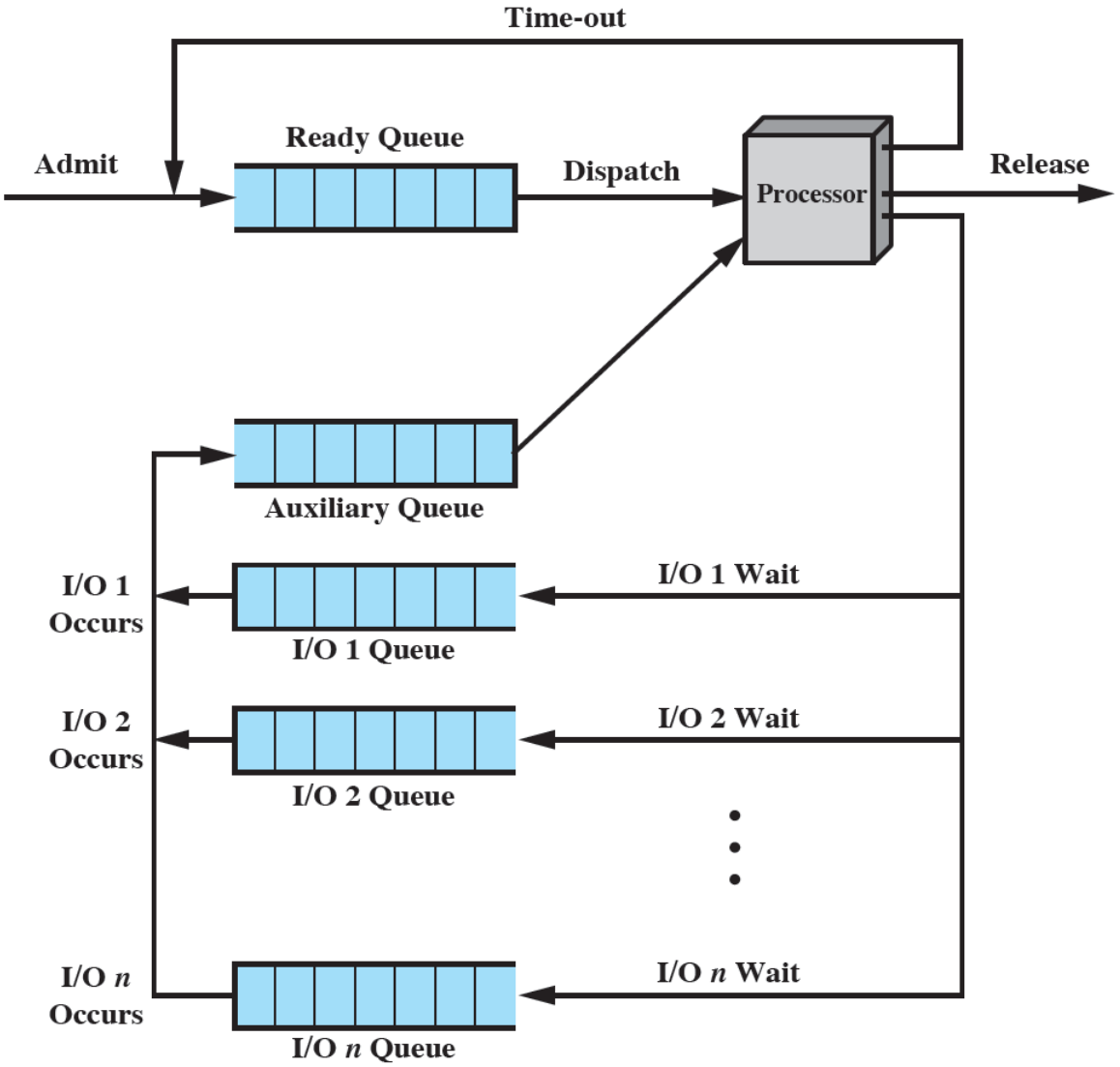
Round Robin

- Uses preemption based on a clock
- Also known as time slicing because each process is given a slice of time before being preempted
- Principal design issue is the length of the time quantum, or slice, to be used
- Particularly effective in a general-purpose time-sharing system or transaction processing system
- One drawback is its relative treatment of processor-bound and I/O-bound processes

Round Robin

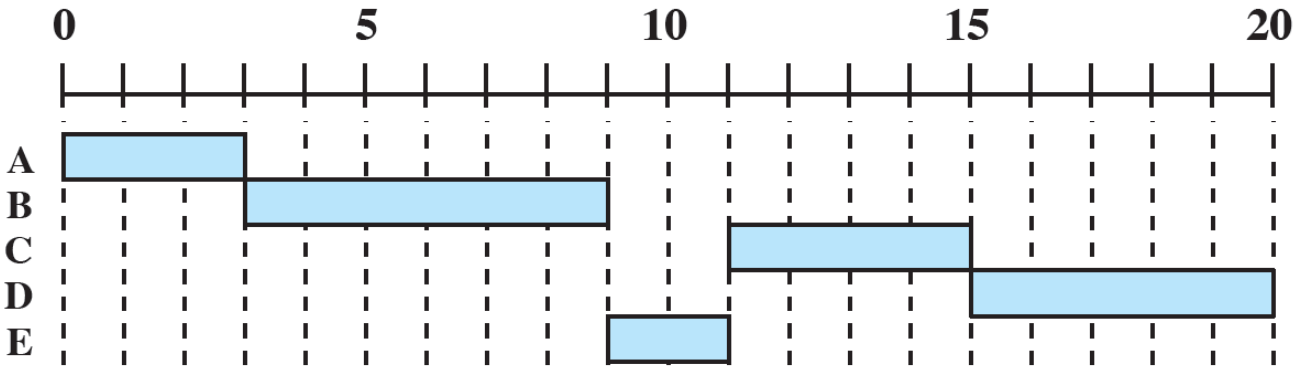


Virtual Round Robin (VRR)



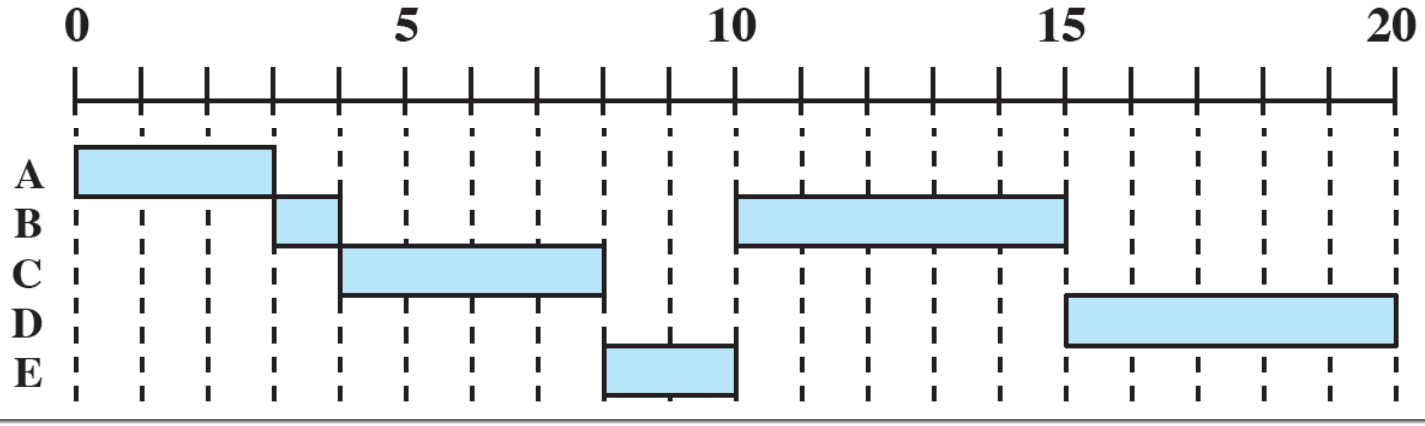
Shortest Process Next (SPN)

- **Nonpreemptive policy**
  - the process with the shortest expected processing time is selected next
- **A short process will jump to the head of the queue**
- **Possibility of starvation for longer processes**
- **One difficulty is the need to know, or at least estimate, the required processing time of each process**
  - If the programmer's estimate is substantially under the actual running time, the system may abort the job



Shortest Remaining Time (SRT)

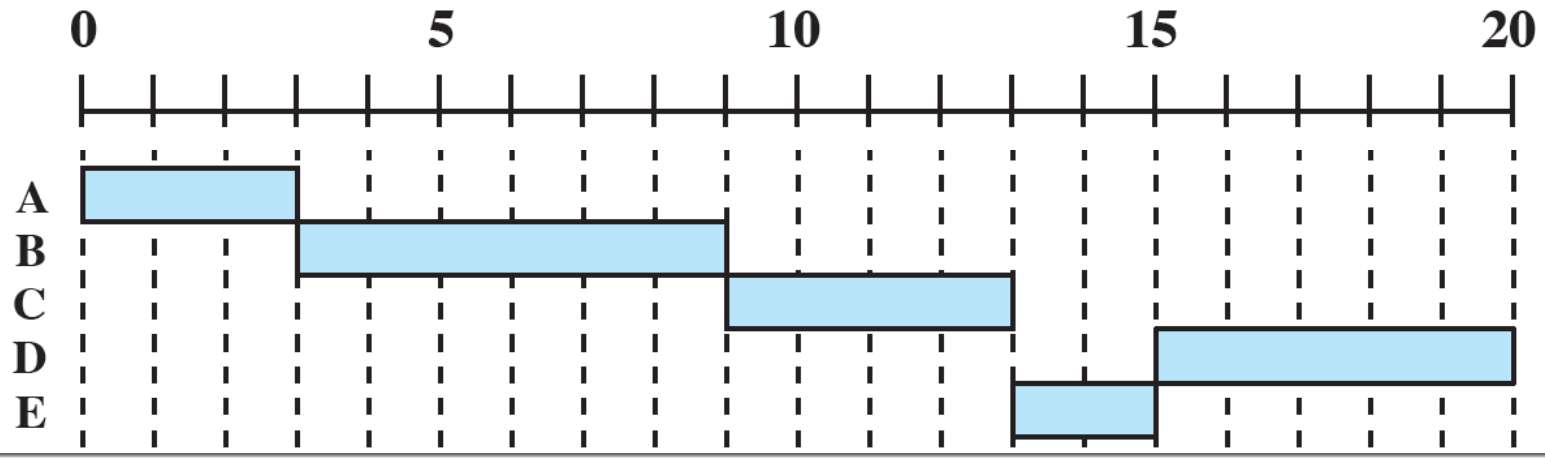
- Preemptive version of SPN
- Scheduler always chooses the process that has the shortest expected remaining processing time
- Risk of starvation of longer processes
- Should give superior turnaround time performance to SPN because a short job is given immediate preference to a running longer job



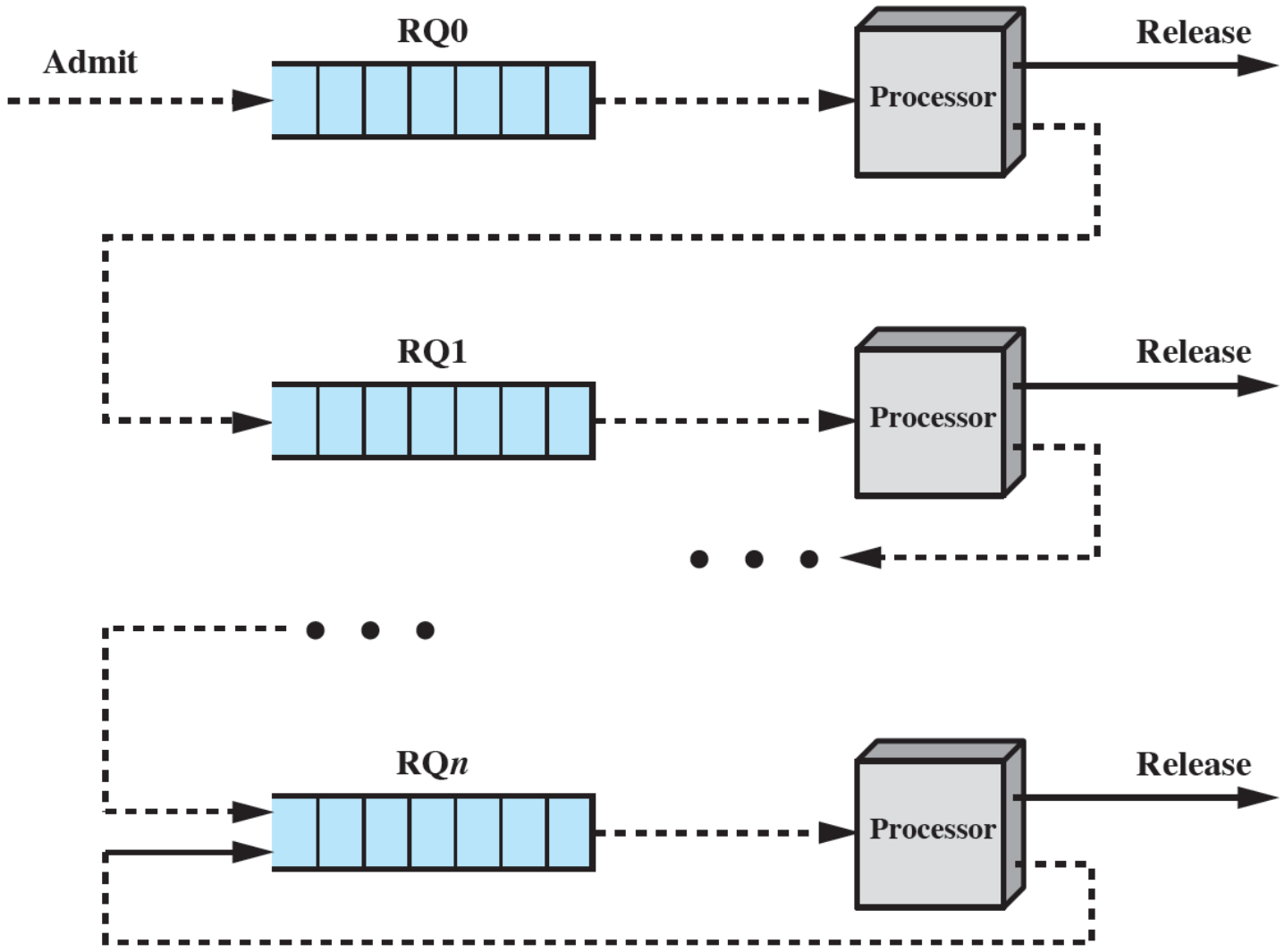
Highest Response Ratio Next (HRRN)

- Chooses next process with the greatest ratio
- Attractive because it accounts for the age of the process
- While shorter jobs are favored, aging without service increases the ratio so that a longer process will eventually get past competing shorter jobs

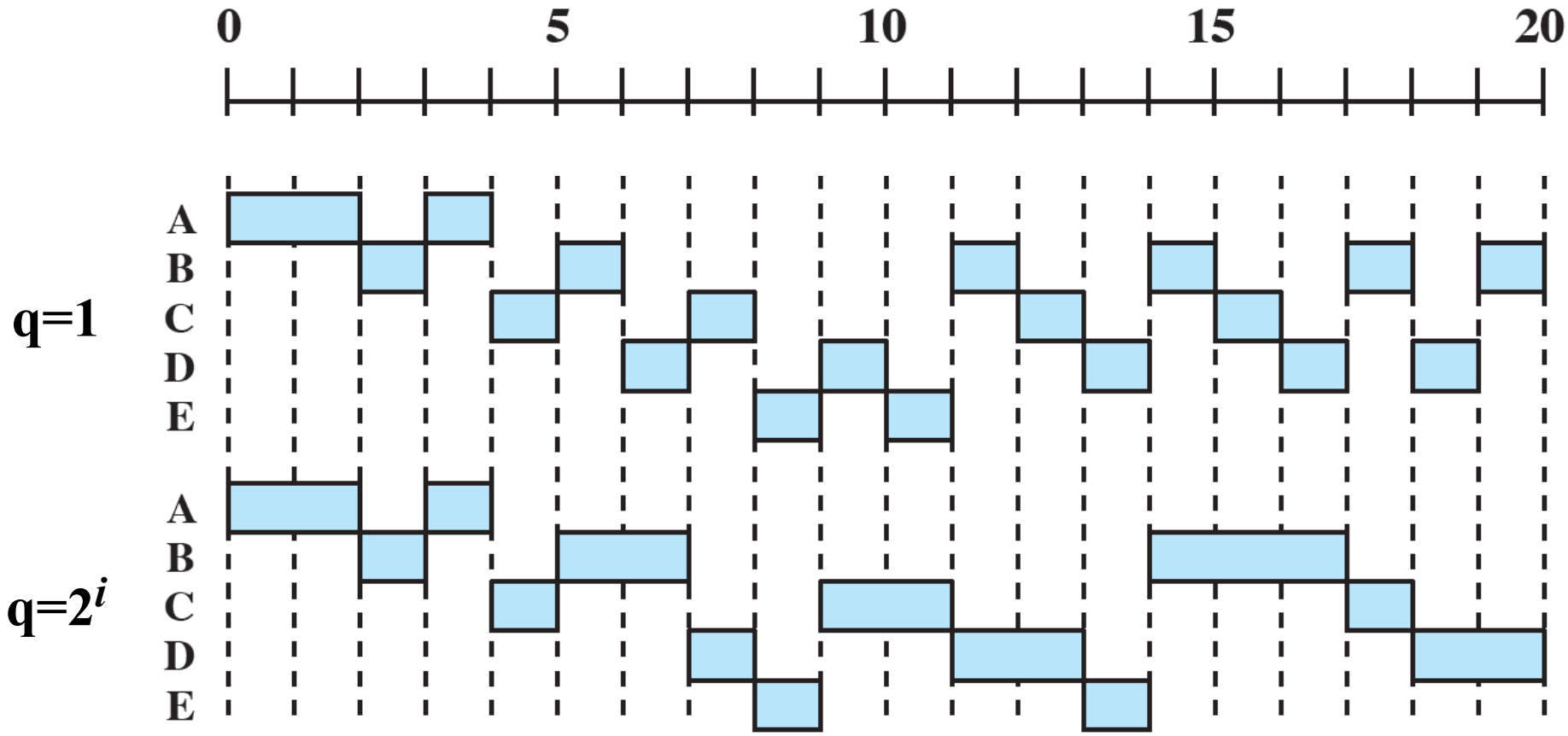
$$Ratio = \frac{time\ spent\ waiting + expected\ service\ time}{expected\ service\ time}$$



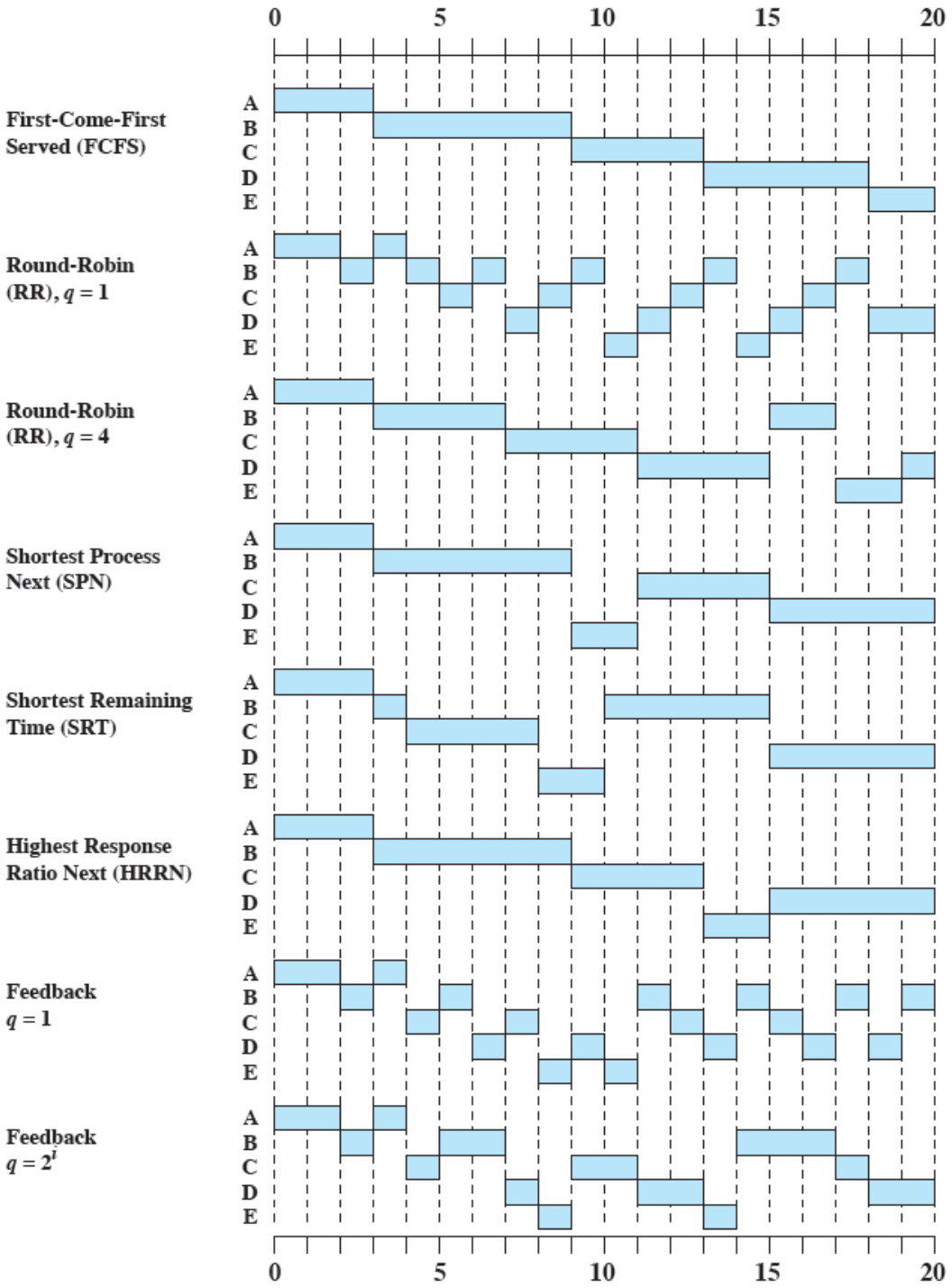
Feedback Scheduling



Feedback Performance



A Comparison of Scheduling Policies



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A Comparison of Scheduling Policies

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

Summary

- **The OS must make three types of scheduling decisions with respect to the execution of processes**
  - Long-term – determines when new processes are admitted to the system
  - Medium-term – part of the swapping function and determines when a program is brought into main memory so that it may be executed
  - Short-term – determines which ready process will be executed next by the processor
- **From a user's point of view**
  - response time is generally the most important characteristic of a system
- **From a system point of view**
  - throughput or processor utilization is important
- **Algorithms:**
  - FCFS
  - Round Robin
  - SPN
  - SRT
  - HRRN
  - Feedback