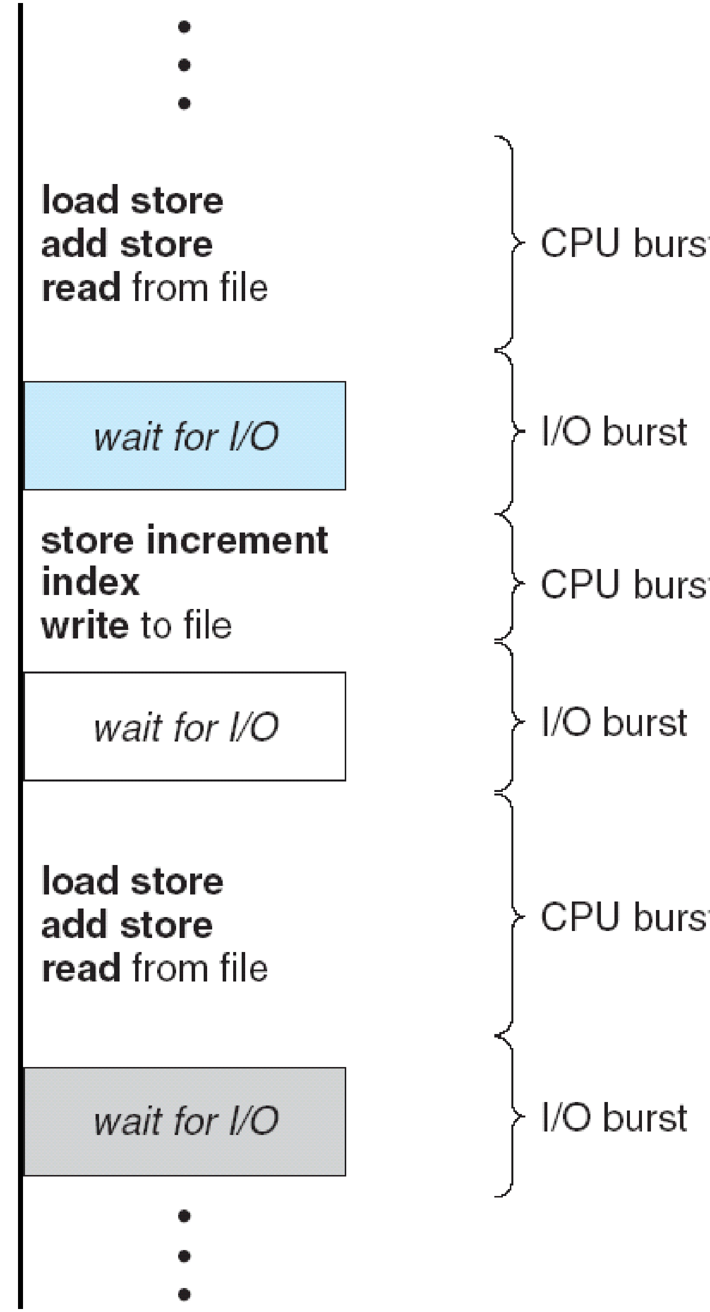
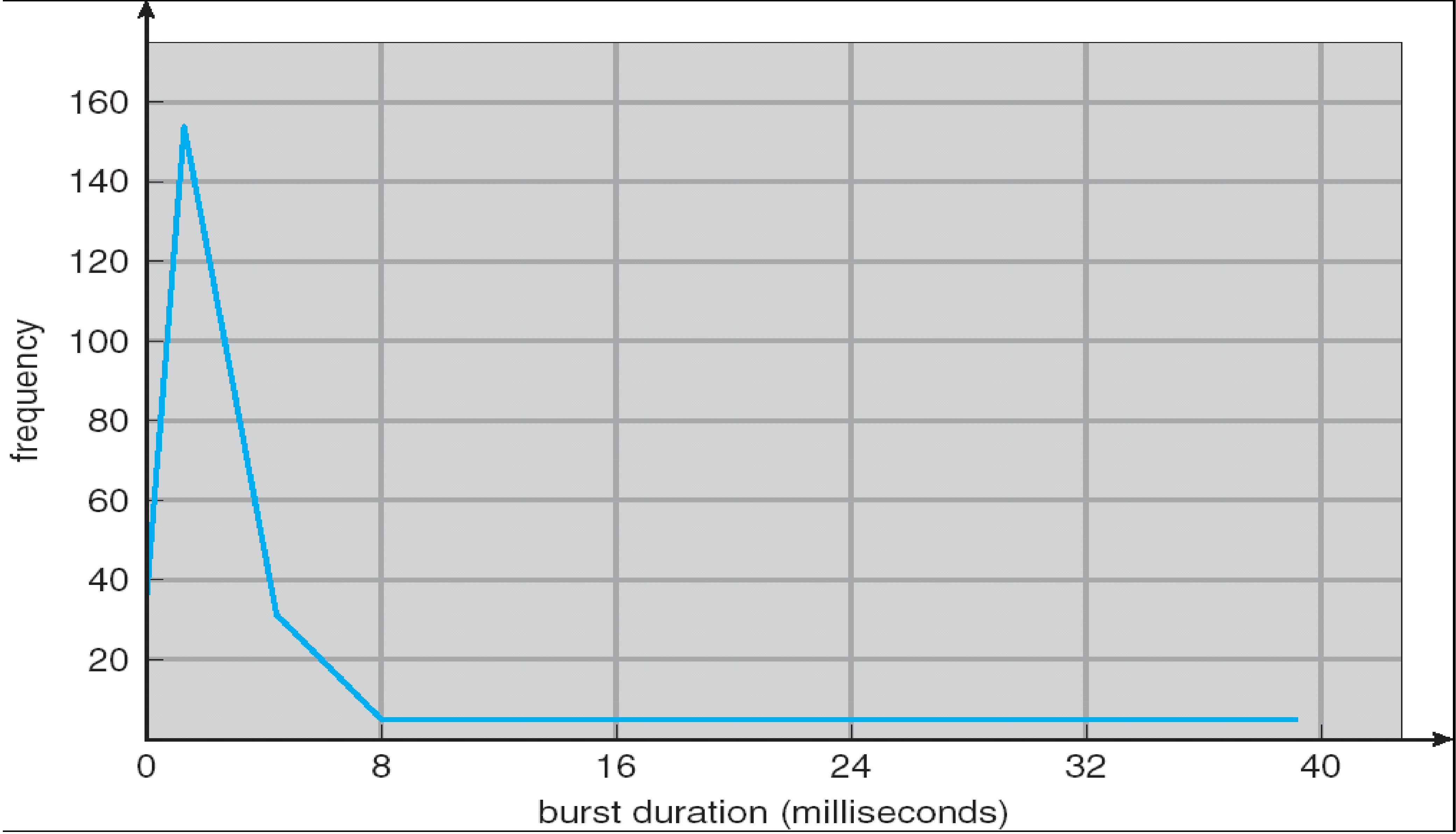
Chapter 5
Scheduling

Images from Silberschatz

CPU usage/IO bursts

- Life time of a single process
- What would an IO bound process look like?
- What would a CPU bound process look like?





- Single process
- What would an IO bound process look like?
- What would a CPU bound process look like?

CPU Scheduler

- Short term scheduler

- Takes process from ready queue and runs it
  - Various algorithms used here.....
  - Data structure? Why?

  - puts it on the CPU

- Takes a process off the CPU and puts it on the ready queue
  - Why?

- Swapping processes around causes a ......

Scheduling events

- Processes moved from the CPU when:
  - Switches from running to waiting state
  - Switches from running to ready state
  - Switches from waiting to ready
  - Terminates

  - What if only first and last are implemented?
    - Why would we ever do this?

Problems

- What happens if a process is preempted while in a system call?
  - Possible bad outcomes?
  - How to fix this?

Dispatcher

- Module/code that puts the process on the CPU
  - Switch context
  - Switch to user mode
  - Restart at correct program counter (PC)

- Dispatch Latency:

Goals

- CPU Utilization
- Throughput
- Turnaround time
- Waiting time
- Response time
- Usually optimize average
  - Sometimes optimize the minimum or maximum
  - Sometimes minimize the *variance*
  - Why? Which values?

Scheduling Algorithms

- First-Come, First-Served (FCFS)
  - Non-preemptive (cooperative!)
  - Data structure?

Process	Burst Time
P_1	24
P_2	3
P_3	3

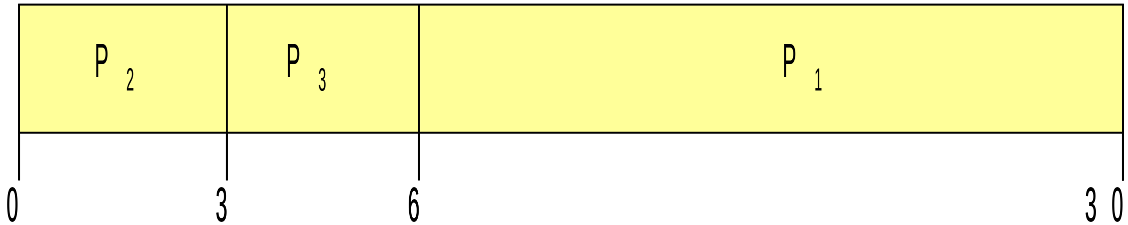
- Suppose that the processes arrive in the order: P_1 , P_2 , P_3
  The Gantt Chart for the schedule is:
- Waiting time
- Average waiting time:

FCFS, cont

Suppose that the processes arrive in the order

$$P_2 , P_3 , P_1$$

- The Gantt chart for the schedule is:



- Waiting time
- Average waiting time:
- *Convoy effect*

- Advantages?

Shortest Job First (SJR)

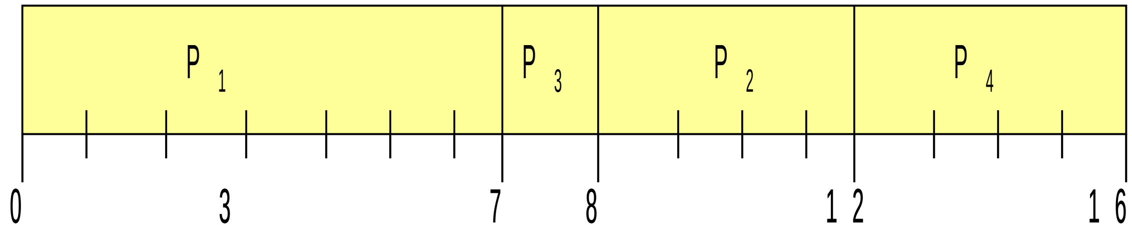
- Choose process who's next CPU *burst* is the shortest
  - Not really shortest JOB first
- May be preemptive (or not)
  - Preemptive (Shortest-Remaining-Time-First (SRTF))

- Gives minimum average waiting time
  - Provably optimal
  - Preemptive
  - With perfect knowledge

Example (cooperative!)

Process	Arrival Time	Burst Time
P_1	0.0	7
P_2	2.0	4
P_3	4.0	1
P_4	5.0	4

- SJF (non-preemptive)

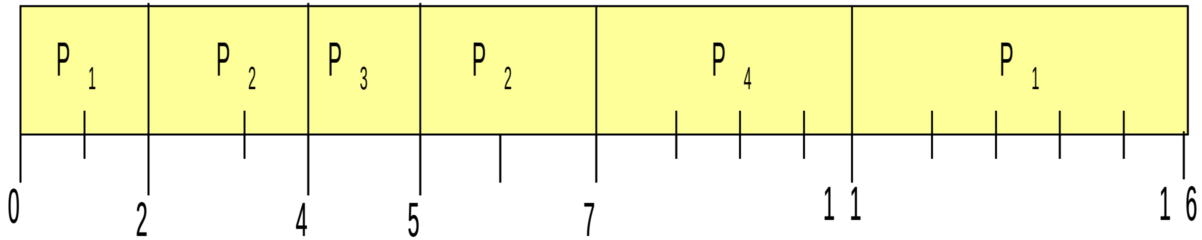


- Average waiting time

Preemptive

Process	Arrival Time	Burst Time
P_1	0.0	7
P_2	2.0	4
P_3	4.0	1
P_4	5.0	4

- SJF (preemptive)



- Average waiting time

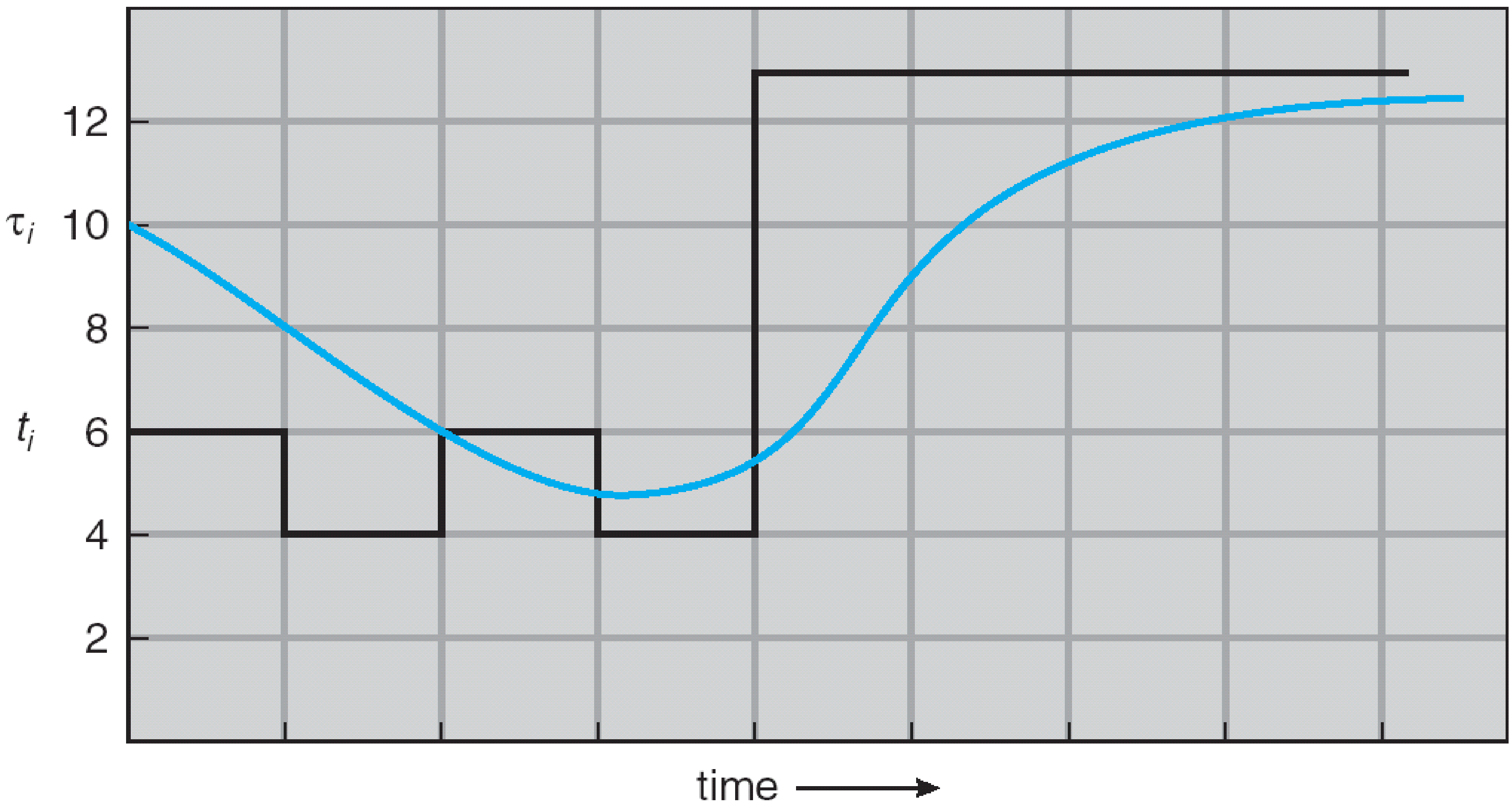
Why is this hard?

- Length of next CPU burst is?

1. $t_n =$ actual lenght of n^{th} CPU burst
2. $\tau_{n+1} =$ predicted value for the next CPU burst
3. $\alpha, 0 \le \alpha \le 1$
4. Define: $$\tau_{n+1} = \alpha\, t_n + (1-\alpha)\tau_n.$$

- Why? What does this mean? What does this look like?

Prediction of next CPU Burst



CPU burst (t_i)		6	4	6	4	13	13	13	...
"guess" (τ_i)	10	8	6	6	5	9	11	12	...

Priority Scheduling

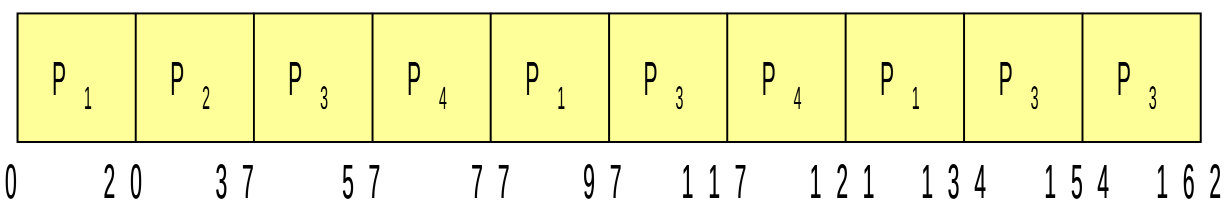
- Give each process a priority (an integer)
- Schedule process with highest priority
  - May be the lowest integer (to make things more confusing)
- Preemptive or not
- SJF is a special case of this
  - What is the priority?
- Where might a problem arise?

Round Robin

- Each process gets some amount of time (10-100 milliseconds)
  - Time quantum/slice
  - Put at the end of the queue when done

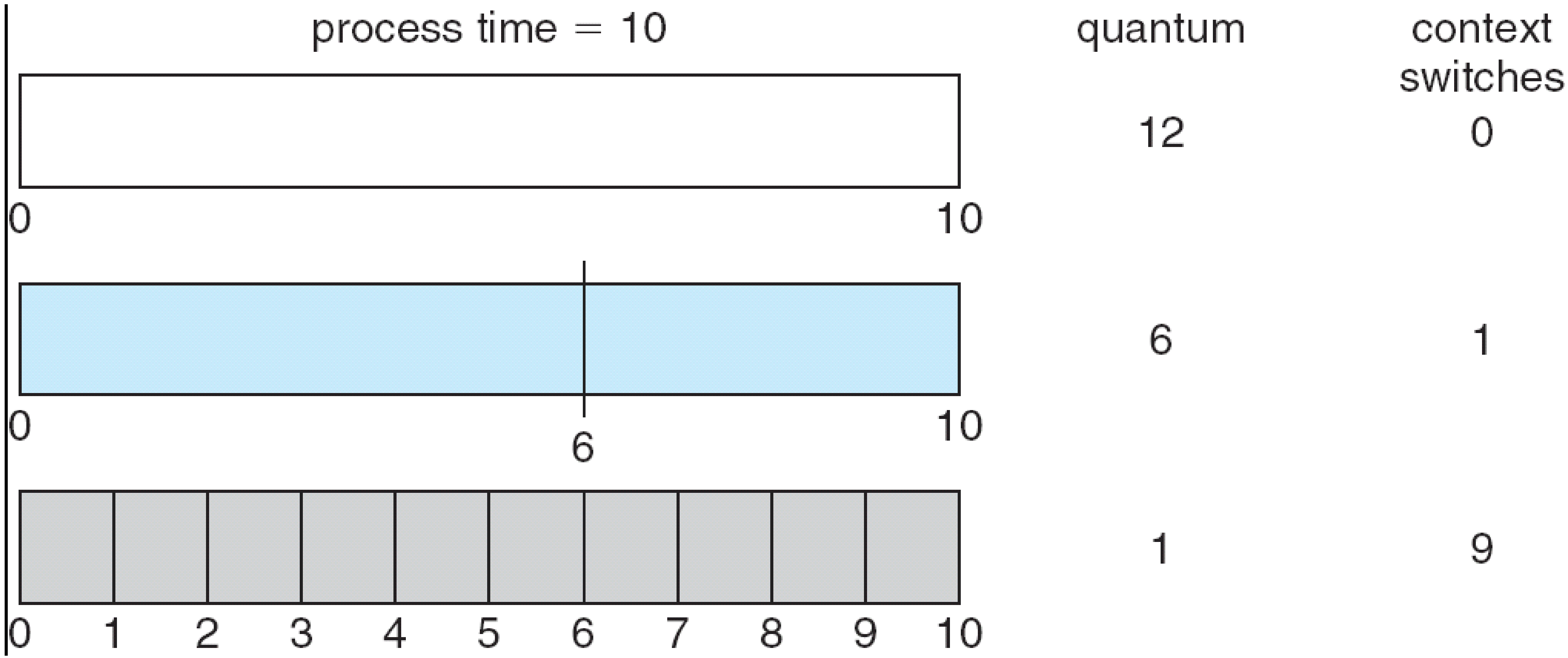
Process	Burst Time
P_1	53
P_2	17
P_3	68
P_4	24

- The Gantt chart is:

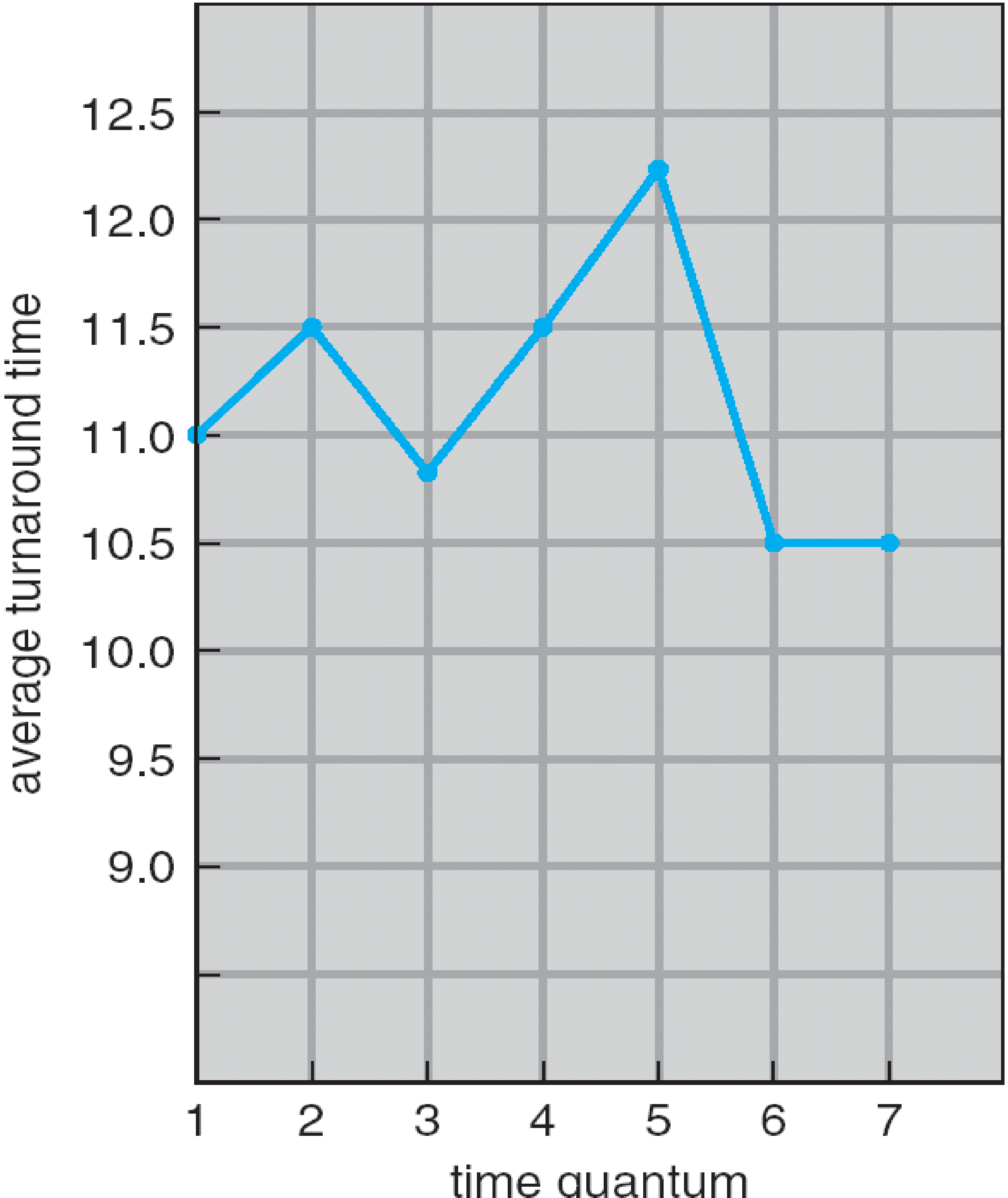


- Typically, higher average turnaround than SJF, but better *response*

Time quanta & context switches



Turnaround time



process	time
P_1	6
P_2	3
P_3	1
P_4	7

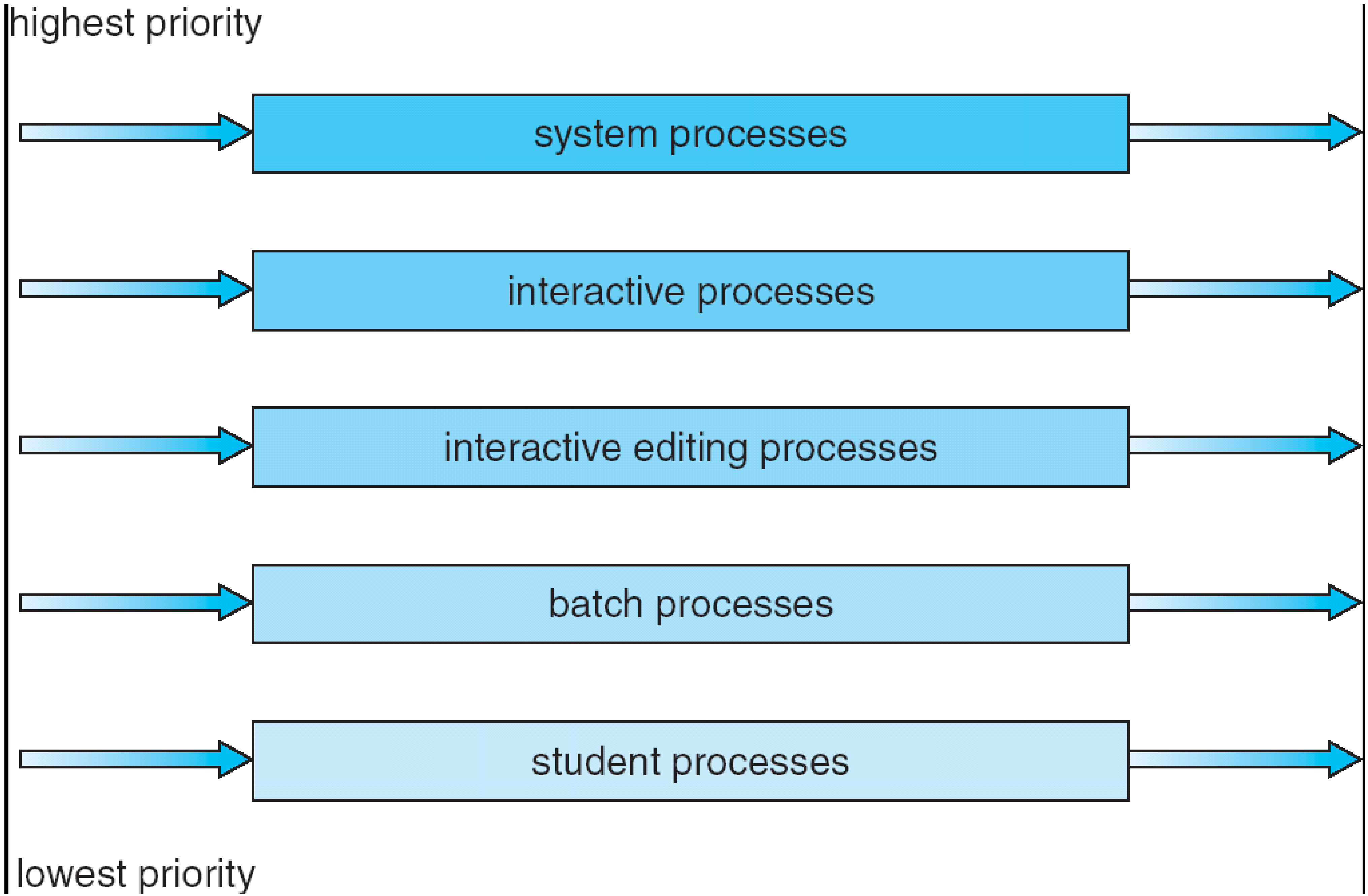
Multilevel Queue Scheduling

- Different Queues, different algorithms
  - Process stays in one queue forever

- Foreground

- Background

- Other categories



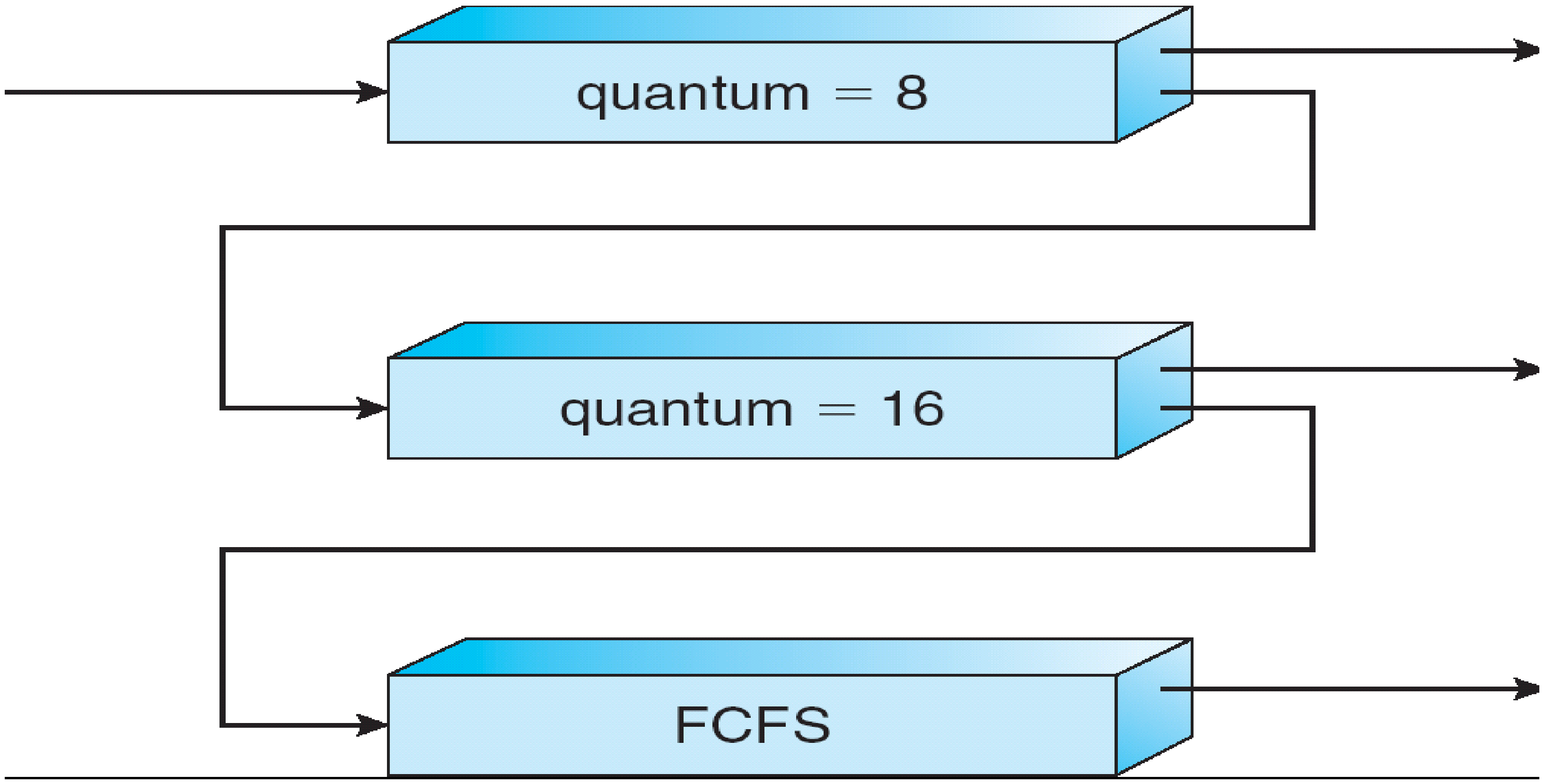
- Absolute vs Time slicing

Multilevel Feedback-Queue Scheduling

- Processes move between queues
  - Use CPU burst information to move processes
  - Aging may play a role
- Defining characteristics
  - number of queues
  - scheduling algorithms for each queue
  - method used to determine when to upgrade a process
  - method used to determine when to demote a process
  - method used to determine which queue a process will enter when that process needs service

Example (p168)

- Three queues
  - Q0 RR with time quantum 8 milliseconds
  - Q1 RR with time quantum 16 milliseconds
  - Q2 FCFS



Multiple-Processor Scheduling

- Asymmetric Multiprocessor

- Symmetric Multiprocessor

- Processor Affinity
  - Soft vs hard

Cont.

- Load Balancing
  - Push migration
  - Pull migration
- Hyperthreading

Thread Scheduling

- Process-contention-scope

- System-contention-scope

Pthreads

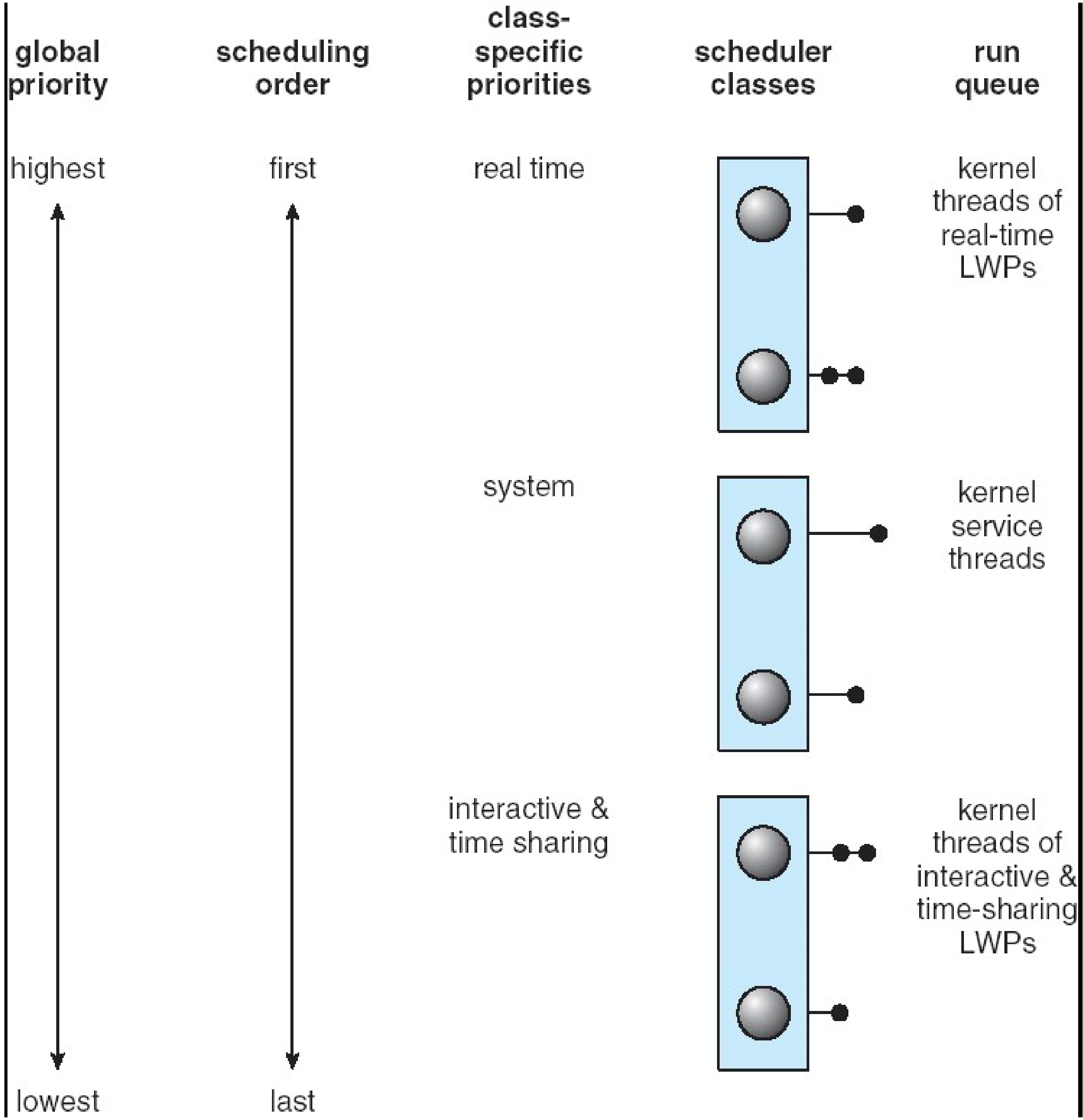
```
#include <pthread.h>
#include <stdio.h>
#define NUM THREADS 5

int main(int argc, char *argv[])
{
     int i;
    pthread t tid[NUM THREADS];
    pthread attr t attr;
    /* get the default attributes */
    pthread attr init(&attr);
    /* set the scheduling algorithm to PROCESS or SYSTEM */
    pthread attr setscope(&attr, PTHREAD SCOPE SYSTEM);
    /* set the scheduling policy - FIFO, RR, or OTHER */
    pthread attr setschedpolicy(&attr, SCHED OTHER);
    /* create the threads */
    for (i = 0; i < NUM THREADS; i++)
        pthread create(&tid[i],&attr,runner,NULL);
    /* now join on each thread */
    for (i = 0; i < NUM THREADS; i++)
        pthread join(tid[i], NULL);
}

 /* Each thread will begin control in this function */
void *runner(void *param)
{
    printf("I am a thread\n");
    pthread exit(0);
}
```

Note the coding standards violations!

Solaris Scheduling

- Priority based
- Classes
  - Real time
  - System
  - Time Sharing
  - Interactive

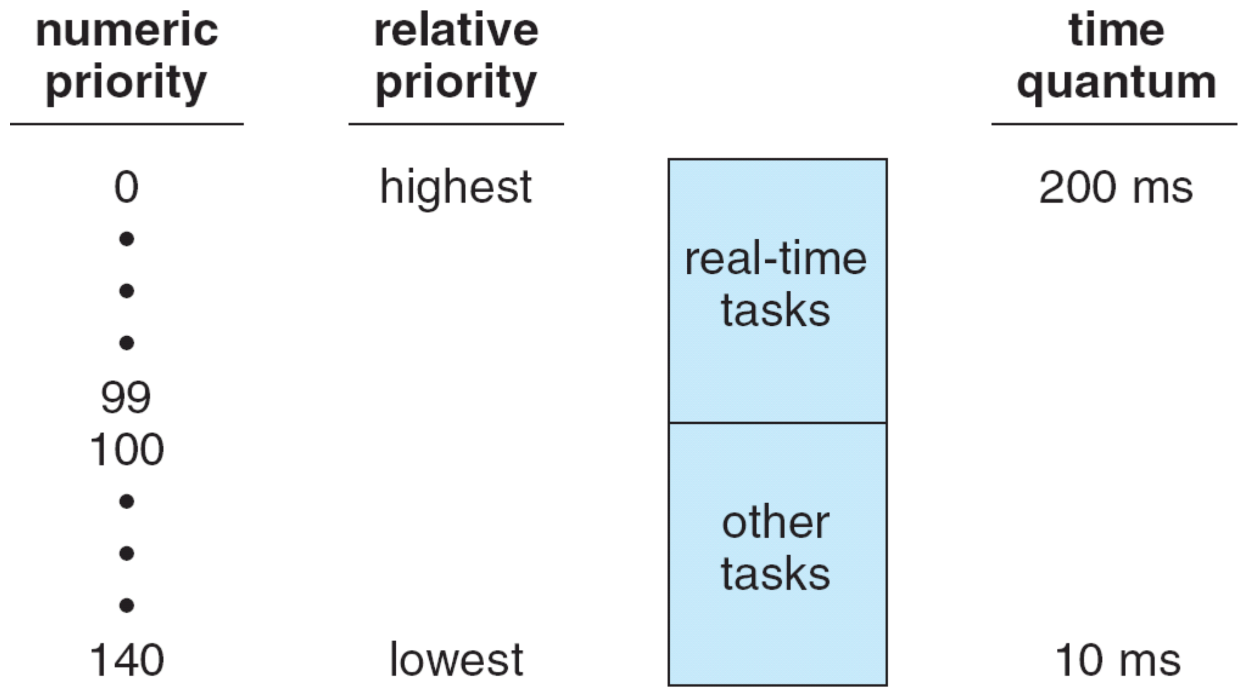
- Solaris 9 adds
  - Fixed priority
  - Fair share

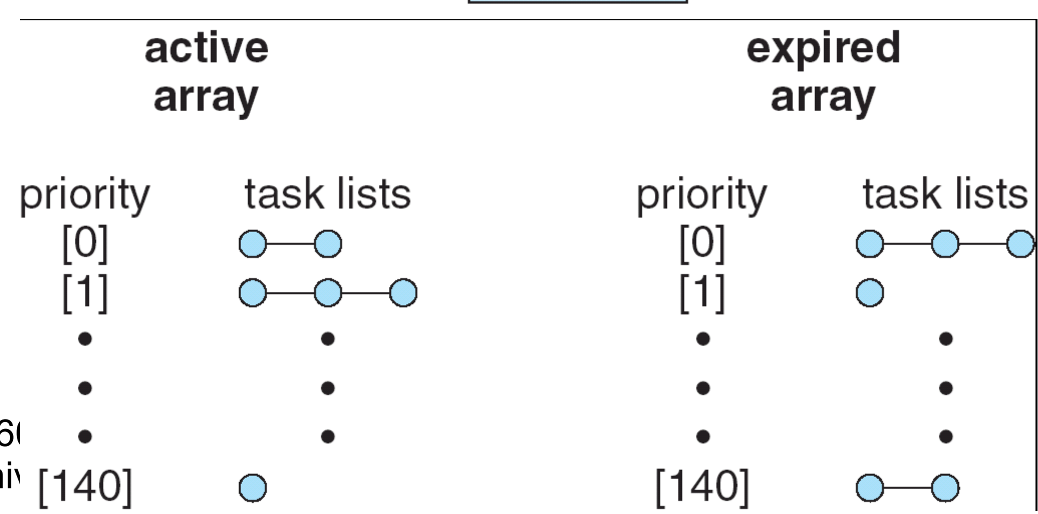


priority	time quantum	time quantum expired	return from sleep
0	200	0	50
5	200	0	50
10	160	0	51
15	160	5	51
20	120	10	52
25	120	15	52
30	80	20	53
35	80	25	54
40	40	30	55
45	40	35	56
50	40	40	58
55	40	45	58
59	20	49	59

Linux

- Preemptive, priority based
- Two priority ranges (lower is better):
  - Real-time: 0-99
  - Nice: 100-140





Algorithm Evaluation

- How to choose a scheduling algorithm?
  - Define goals
    - Minimize wait time? Minimize response time? Maximize CPU utilization?
- Deterministic modeling
- Queuing modeling (queuing network analysis)
  - Little's formula
- Simulations
- Build it