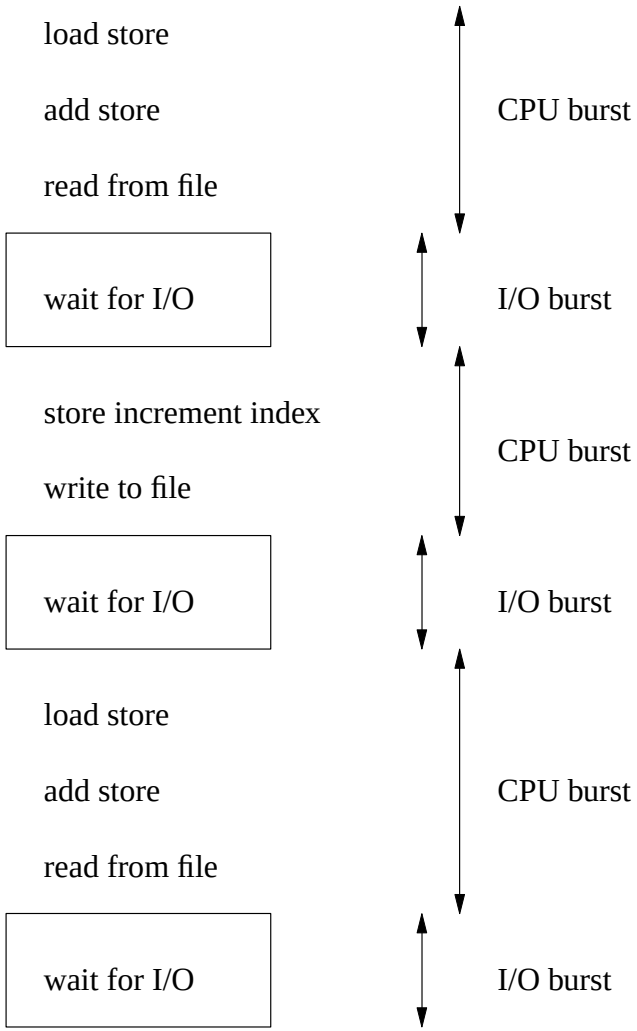
Process scheduling

- See Silberschatz Chapter 5

Process boundness

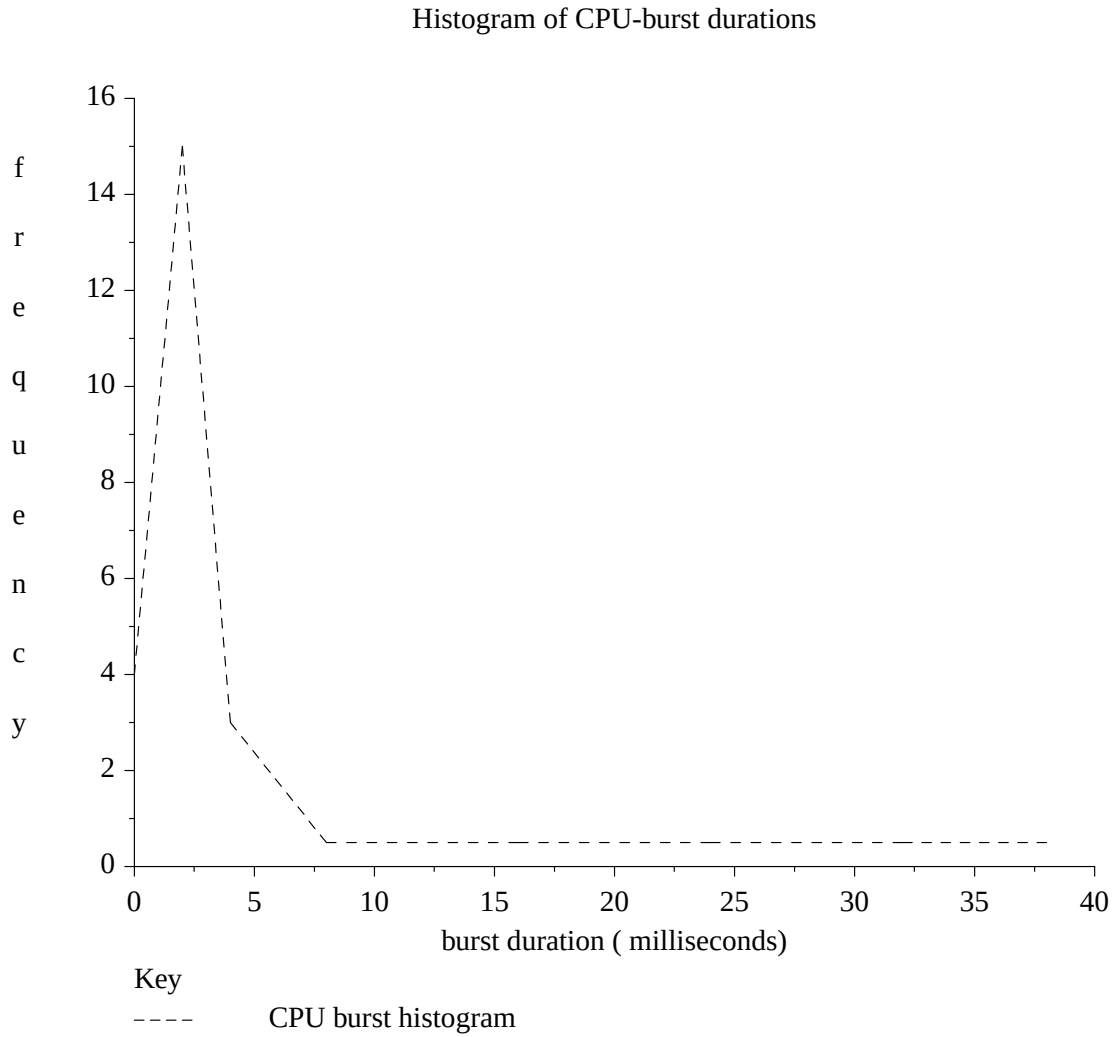
- Processes can be described as either:
  - I/O-bound process - spends more time doing I/O than computations, many short CPU bursts
  - CPU-bound process - spends more time doing computations; fewer but long CPU bursts

Alternating Sequence of CPU and I/O Bursts



Silberschatz Fig 5.1

Histogram of CPU-burst Times



Silberschatz Fig 5.2

Preemptive vs non-preemptive

- Preemptive scheduling occurs when
  - CPU scheduler removes a process from the running state to allow another process to run.

- Non-preemptive scheduling means that
  - process runs to completion or performs an I/O wait or relinquishes control itself.

Scheduling Criteria

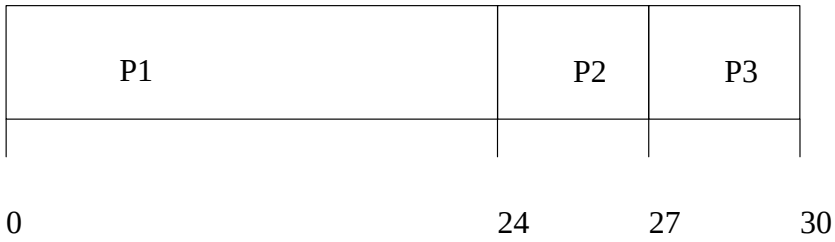
- define terms
- Waiting time = time spent in ready queue
- Turnaround time = time when process has completed

First-Come, First-Served (FCFS) Scheduling

Process	CPU Burst Time
P1	24
P2	3
P3	3

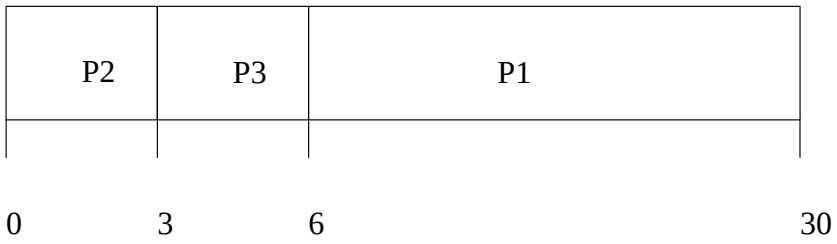
- All processes arrive at time 0 but in the order `P1`, `P2`, `P3`

First-Come, First-Served (FCFS) Scheduling



- average waiting time: $(0 + 24 + 27)/3 = 17$

First-Come, First-Served (FCFS) Scheduling

- Suppose that the processes arrive in the order `P2`, `P3`, `P1`
- The time chart for the schedule is:
- 

First-Come, First-Served (FCFS) Scheduling

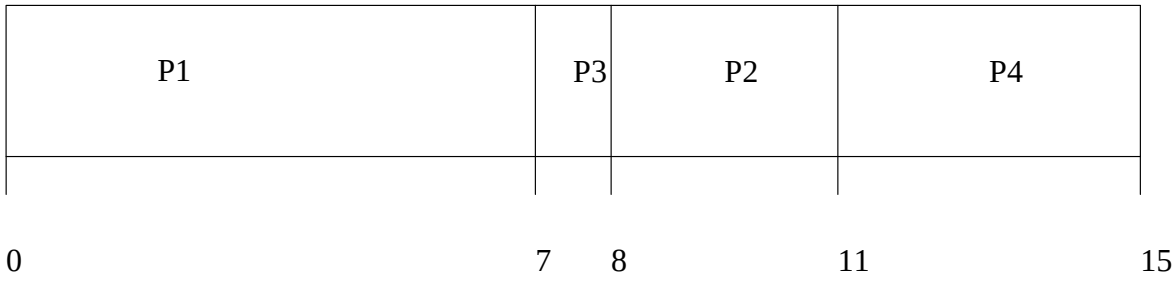
- Waiting time for P1 = 6; P2 = 0; P3 = 3
- Average waiting time: (6 + 0 + 3)/3 = 3
- much better than previous case.
- Convoy effect long process after short process

Shortest-Job-First (SJF) Scheduling

- Allocate CPU to process with smallest CPU burst time.
- Two schemes:
  - nonpreemptive - once CPU given to the process it cannot be preempted until completes its CPU burst.
  - preemptive - if a new process arrives with CPU burst length less than remaining time of current executing process, preempt
  - this scheme is know as the Shortest-Remaining-Time-First (SRTF)
- SJF is optimal - gives minimum average waiting time for a given set of processes

Example of Non-Preemptive SJF

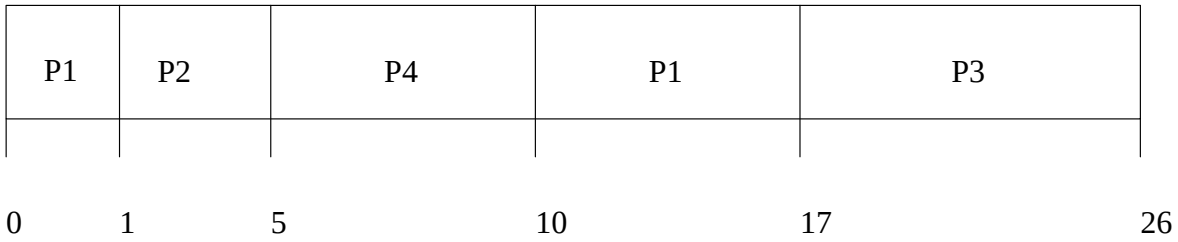
Process	Arrival Time	CPU Burst Time
P1	0	7
P2	2	3
P3	4	1
P4	5	4



- Average waiting time = $(0 + (8 - 2) + (7 - 4) + (11 - 5))/4 = 3.75$

Example of Preemptive SJF

Process	Arrival Time	Burst time
P1	0	8
P2	1	4
P3	2	9
P4	3	5



- Average waiting time = $((10 - 1) + 0 + (17 - 2) + (5 - 3))/4 = 6.5$

Priority Scheduling

- a priority number (integer) is associated with each process

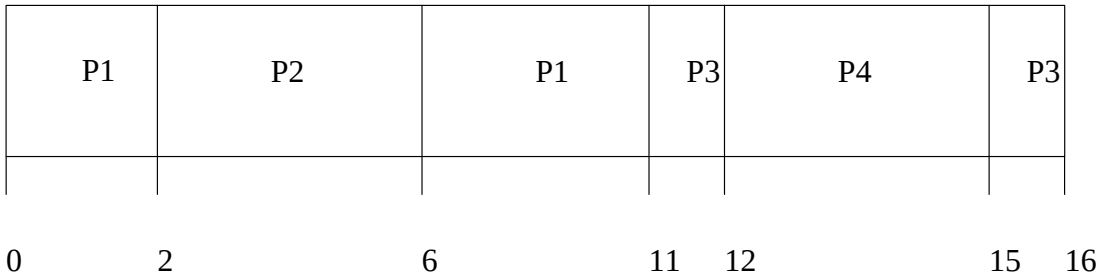
- the CPU is allocated to the process with the highest priority (smallest integer is the highest priority)
  - Preemptive
  - nonpreemptive

Priority Scheduling

- SJF is a priority scheduling where priority is the predicted next CPU burst time
- Problem -> Starvation - low priority processes may never execute
- Solution -> Aging - as time progresses increase the priority of the process

Example of Preemptive Priority

Process	Arrival Time	CPU time	Priority
P1	0	7	2
P2	2	4	1
P3	4	2	4
P4	12	3	3



- Average waiting time = $((6-2)+0+((11-4)+(15-12))+0)/4 = 3.5$

Round Robin (RR)

- Each process gets a unit of CPU time (time quantum), usually 10-200 milliseconds.
- After this time has elapsed, the process is preempted and added to the end of the ready queue.
- If there are n processes in the ready queue and the time quantum is q, then each process gets $\frac{1}{n}$ of the CPU time in chunks of at most q time units

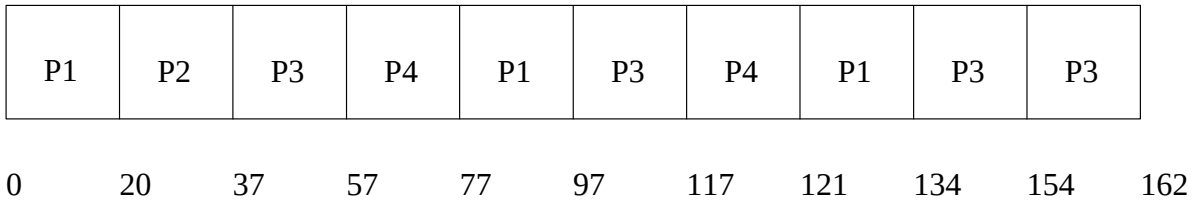
Round Robin (RR)

- No process waits more than $(n-1)q$ time units

- Performance
  - if we use a large quanta then round robin behaves as FCFS
  - if we use a too small quanta then the overhead is too high
    - thus it must be large with respect to context switch

Example of RR with Time Quantum = 20

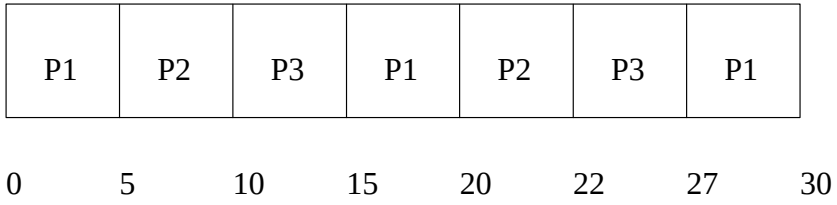
Process	CPU Burst Time
P1	53
P2	17
P3	68
P4	24



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

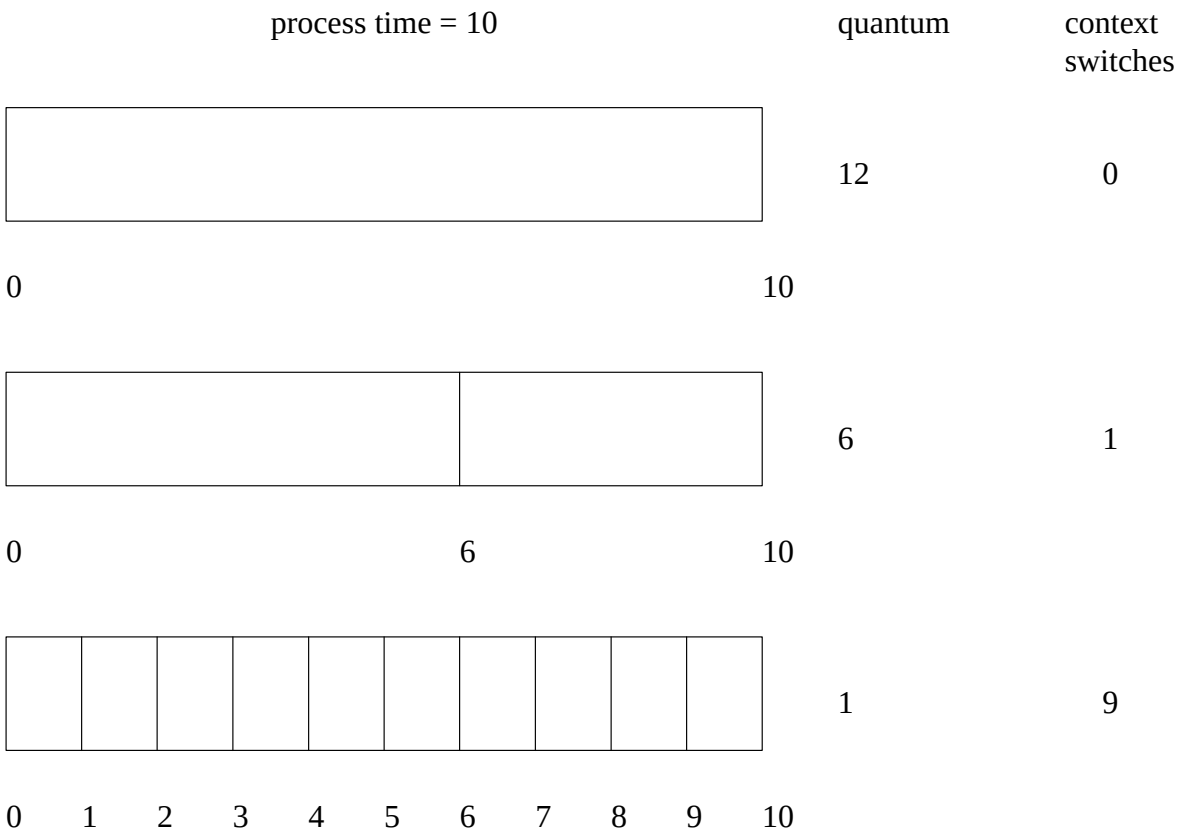
Simpler example of RR with Time Quantum = 5

Process	CPU Burst Time
P1	13
P2	7
P3	10



- Waiting time for P1 = 0 + (15 – 5) + (27 – 20) = 17
- Waiting time for P2 = 5 + (20 – 10) = 15
- Waiting time for P3 = 10 + (22 – 15) = 17
- Average waiting time = (17 + 15 + 12)/3 = 14. 667

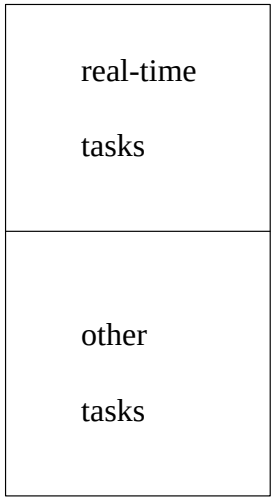
Time Quantum and Context Switch Time



Real-life scheduling

- Both Windows and Unix operating systems use scheduling algorithms which incorporate pre-emptive priority mechanisms
- The Unix command nice can be used to alter the priority of a process
- The Linux scheduler favours I/O bound over CPU bound processes
  - the Linux kernel also has the ability to change duration of quantum (time-slice)

Priorities and time slice length in Linux



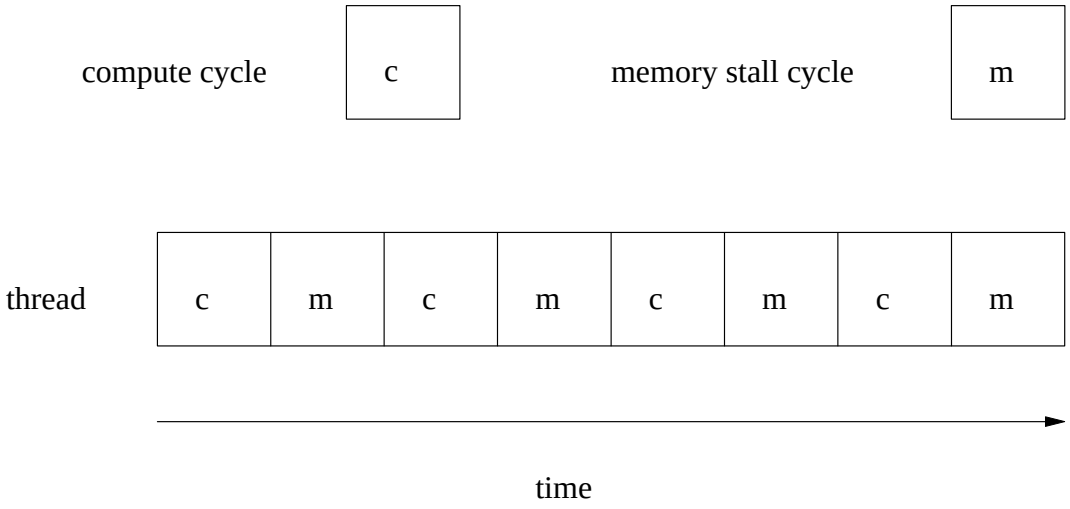
Multiple-Processor Scheduling

- CPU scheduling more complex when multiple CPUs are available
- Homogeneous processors within a multiprocessor
- Asymmetric multiprocessing
  - only one processor accesses the system data structures, alleviating the need for data sharing
- Symmetric multiprocessing (SMP)
  - each processor is self-scheduling, all processes in common ready queue, or each has its own private queue of ready processes

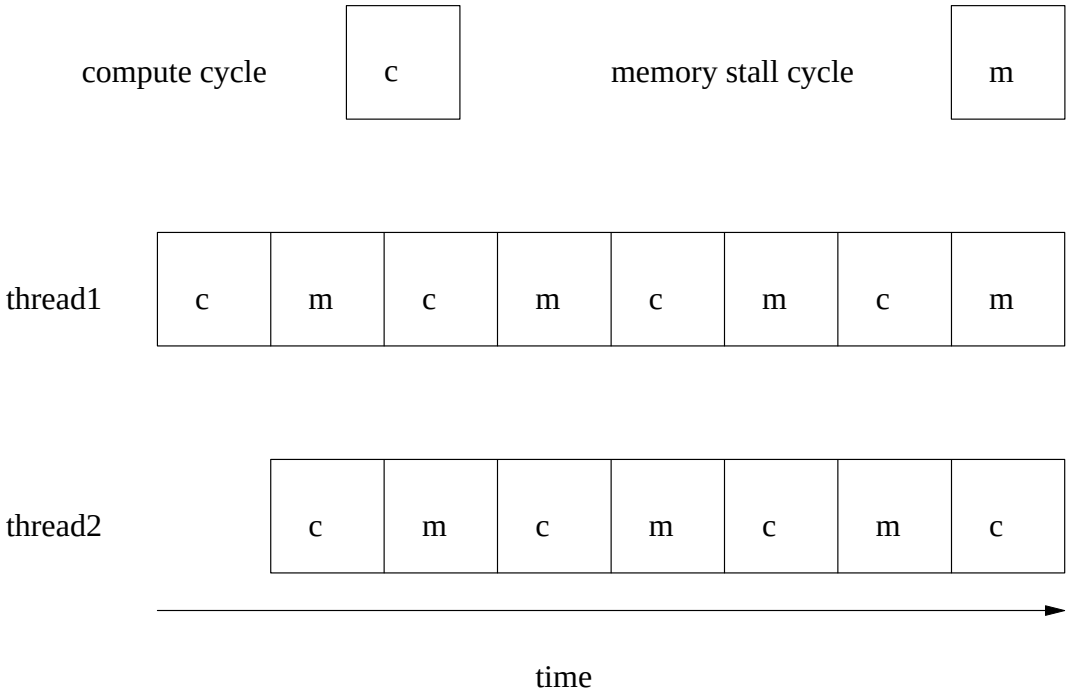
Multicore Processors

- Recent trend to place multiple processor cores on same physical chip
- Faster and consume less power
- Multiple threads per core
- Takes advantage of memory stall to make progress on another thread while memory retrieve happens cf. CPU and I/O bound process definition

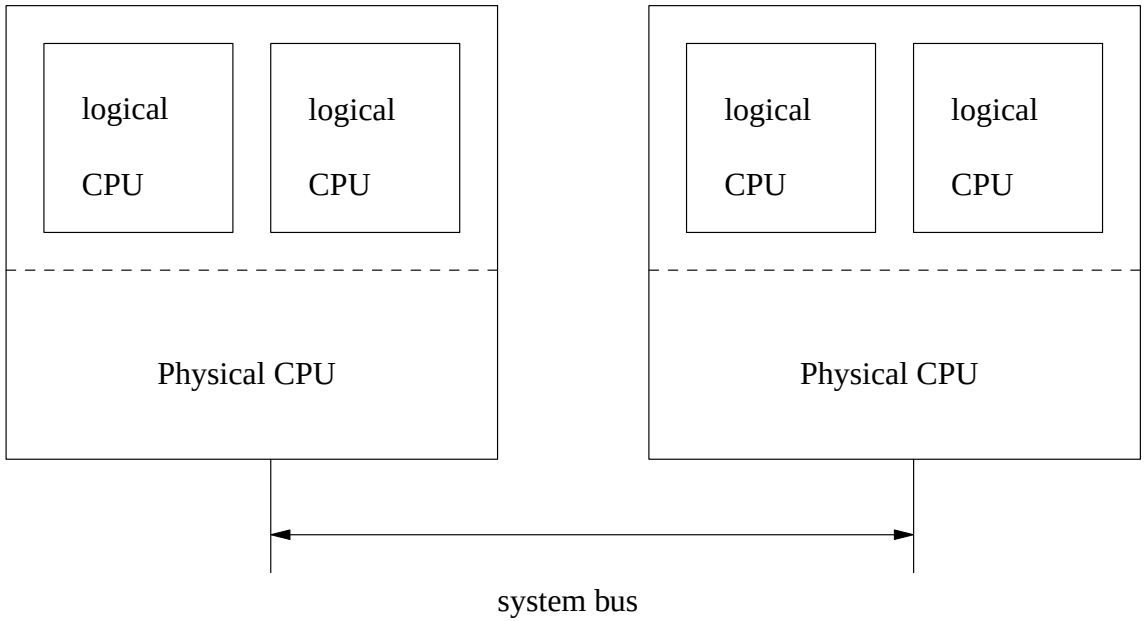
Single thread activity



Multithreaded multicore activity



Thread scheduling on multicore procesors



- Scheduling takes place between threads on logical CPUs - Silberschatz (pg 205, Ed 8) suggests algorithms such as round-robin and priority/urgency are employed at this level