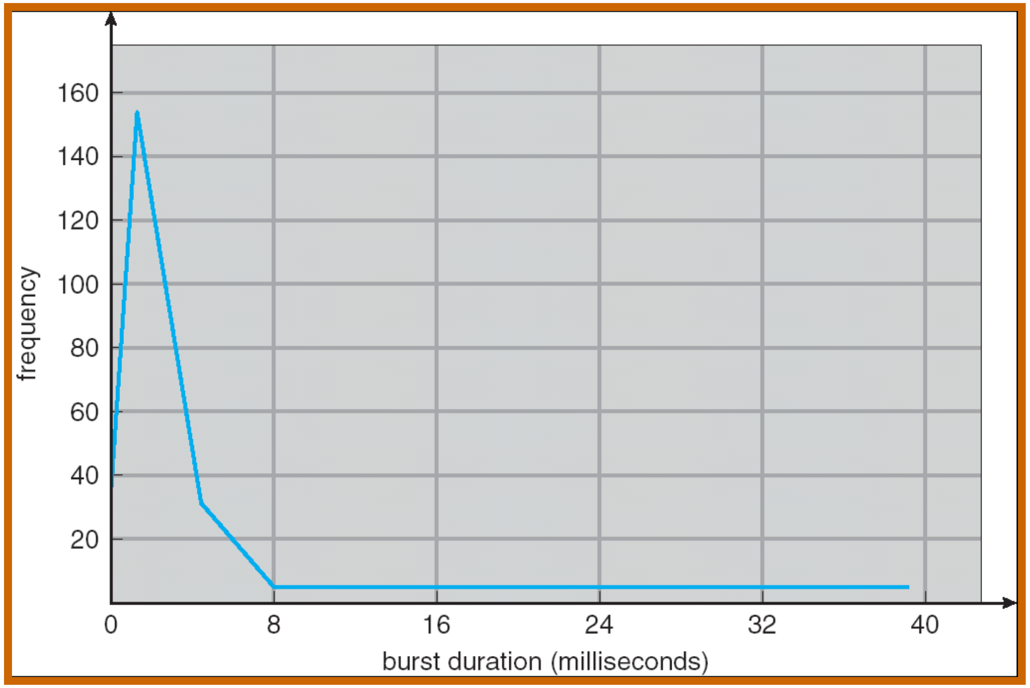
CPU Scheduling

Properties of Processes

- CPU–I/O Burst Cycle
  - Process execution consists of a cycle of CPU execution and I/O wait.
- CPU burst distribution:



CPU Scheduler

- Selects from among the processes that are ready to execute.
- **Non-preemptive** CPU scheduling decisions may take place when a process:
  - Switches from running to waiting state.
  - Terminates.
- **Preemptive** scheduling decisions may happen when a process:
  - Switches from waiting to ready.
  - Switches from running to ready state.
  - Has its time slice expire.

Dispatcher

- Dispatcher module gives control of the CPU to the process selected by the scheduler; this involves:
  - Switching context.
  - Switching to user mode.
- **Dispatch latency** – time it takes for the dispatcher to stop one process and start another running.

Scheduling Criteria

- What constitutes a “good” scheduling algorithm?
- **CPU utilization** – Keep the CPU as busy as possible.
- **Throughput –** # of processes that complete their execution per time unit.
- **Turnaround time** – amount of time to execute a particular process.

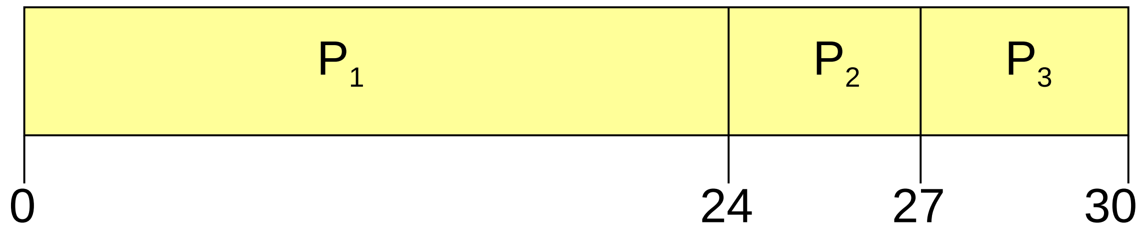
Scheduling Criteria

- **Waiting time** – amount of time a process waits in the ready queue.
  - Advantage over turnaround time: less dependent on specifics of process.
- **Response time** – time it takes from when a request was submitted until the first response is produced.
  - Appropriate for time sharing systems.

First Come First Serve Scheduling (FCFS)

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:



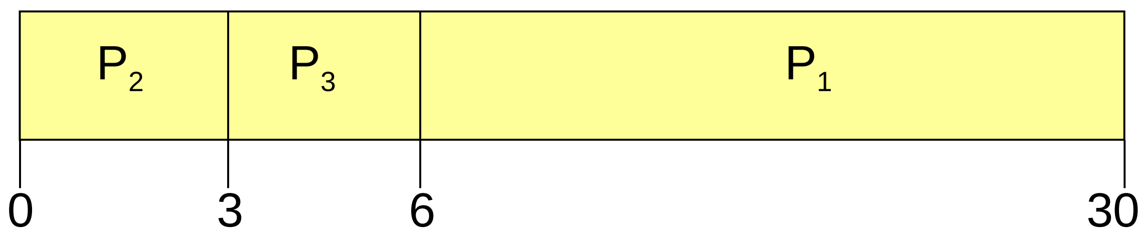
- Waiting time for $P_1 = 0$; $P_2 = 24$; $P_3 = 27$.
- Average waiting time: $(0 + 24 + 27)/3 = 17$.

Short Job First Scheduling

- Associate with each process with the length of its next CPU burst.
- Use these lengths to schedule the process with the shortest time.
- SJF is optimal – gives minimum average waiting time for a given set of processes.

SJF Example

- Same three processes as before, different ordering:



- Waiting time for $P_1 = 6; P_2 = 0; P_3 = 3$
- Average waiting time: $(6 + 0 + 3)/3 = 3$

SJF Variants

- **Non-preemptive** – 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)

Predicting CPU Bursts

- No way to know the length of the next CPU burst.
- Assume that future behavior will be like past behavior.
- Maintain an exponential average:

$$\tau_{n+1} = \alpha t_n + (1-\alpha)\tau_{n-1}$$

Priority Scheduling

- A priority number (integer) is associated with each process.
- The CPU is allocated to the process with the highest priority (smallest integer = highest priority.)
  - Preemptive.
  - Non-preemptive.
- Problem: starvation – low priority processes may never execute.
- Solution: aging – as time progresses increase the priority of the process.

Round Robin

- Each process gets a small **quantum**, usually 10-100 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 $1/n$ of the CPU time in chunks of at most q time units at once.
- No process waits more than $(n-1)q$ time units.

Round Robin Performance

- *q* large ->FIFO
- *q* small -> *q* must be large with respect to context switch, otherwise overhead is too high
- In general, RR has higher turnaround time than SJF, but better response time.

Multi-level Queue

- Ready queue is partitioned into separate queues. For example:
  - foreground (interactive)
  - background (batch)
- Each queue has its own scheduling algorithm
  - foreground – RR
  - background – FCFS
- Can maintain responsiveness in the face of CPU bound tasks.

Multi-level Queue

- Scheduling must be done between the queues
- Fixed priority scheduling; (i.e., serve all from foreground then from background).
  - Possibility of starvation.
- Time slice – each queue gets a certain amount of CPU time which it can schedule amongst its processes, e.g.:
  - 80% to foreground in RR
  - 20% to background in FCFS

Multi-level Feedback Queue

- A process can move between the various queues.
  - Aging can be implemented this way.
  - Processes can be organized according to their CPU burstiness.
  - I/O bound processes will end up in higher level queues.
- (Some of the same goals can be met with dynamic priority based schemes.
  - Processes get priority boosts based on being I/O bound.)

Multi-level Feedback Queue

- Multilevel-feedback-queue scheduler defined by the following parameters:
  - 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.

Multi-processor Scheduling

- Some new issues arise:
  - Processor affinity.
  - Load balancing.
    - Push vs. Pull migration.
  - Hyperthreading aware scheduling.

Real Time Scheduling

- **Hard real-time systems** – required to complete a critical task within a *guaranteed* amount of time.
  - Challenging to implement.
- **Soft real-time systems** – requires that critical processes receive priority over less fortunate ones.
  - Just requires a mechanism for very high priority processes.

Thread Scheduling

- Process contention scope (PCS):
  - Library scheduling of threads within a process.
- System contention scope (SCS):
  - Scheduling of kernel threads.

Algorithm Evaluation

- Develop some model of the computer system and scheduler.
  - “Model” may be a complete implementation.
  - “Model” may be an abstract description of the scheduling algorithm: “RR”.
- See how the model performs on sample input.
  - Simple description of a set of jobs.
  - Trace information from a running system.
  - Data generated from probability distributions.

Acknowledgments

- Portions of these slides are taken from Power Point presentations made available along with:
  - Silberschatz, Galvin, and Gagne. Operating System Concepts, Seventh Edition.
- Original versions of those presentations can be found at:
  - http://os-book.com/