Comp 204: Computer Systems and Their Implementation

Lecture 12: Scheduling Algorithms cont'd

Today

- Scheduling continued
  - Multilevel queues
  - Examples
  - Thread scheduling

Question

- A starvation-free job-scheduling policy guarantees that no job waits indefinitely for service. Which of the following job-scheduling policies is starvation-free?

  a) Round-robin
  b) Priority queuing
  c) Shortest job first
  d) Youngest job first
  e) None of the above

Answer: a
Round Robin – this gives all processes equal access to the processor. The other techniques each select some "types" of processes to others (e.g. short processes, high priority processes etc).

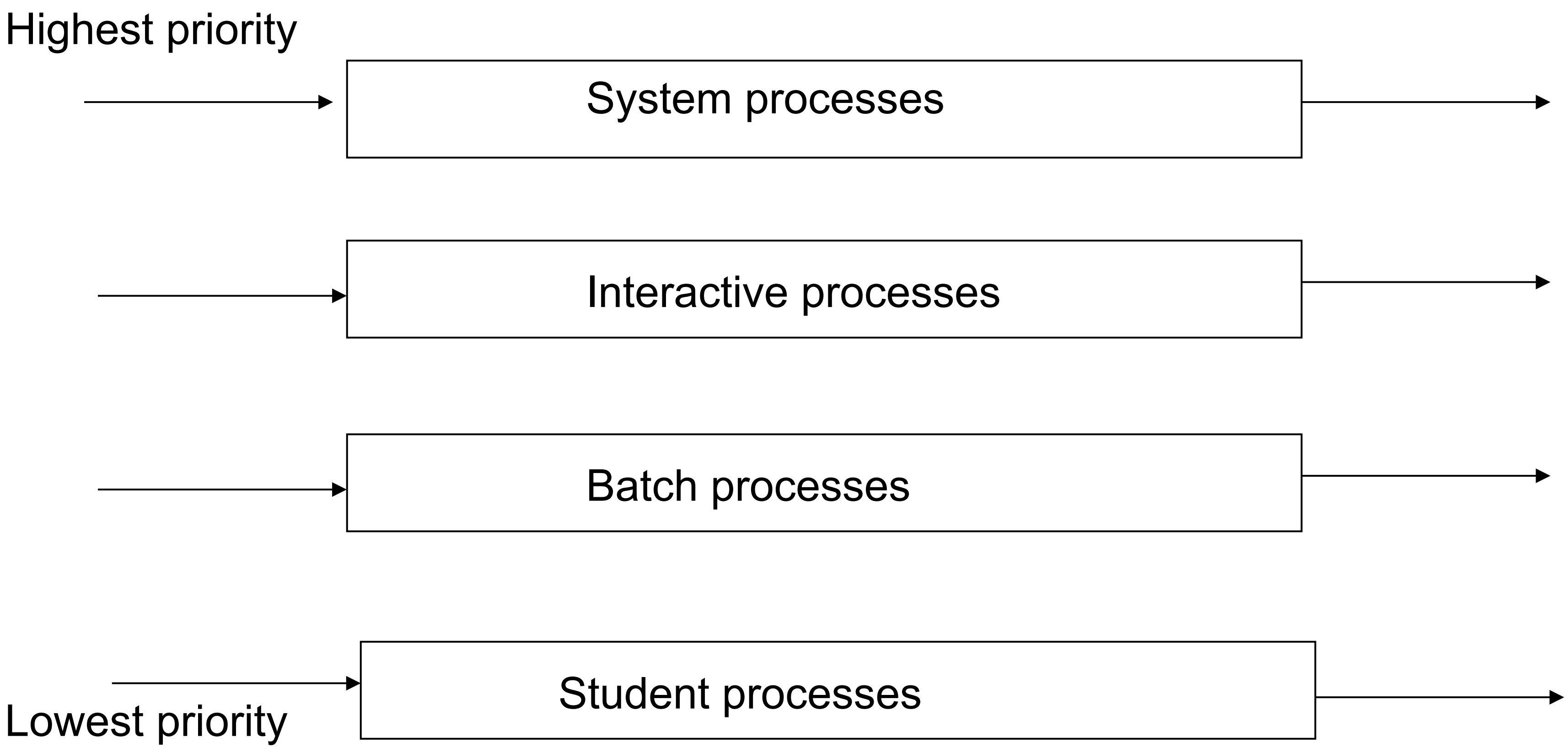
Question?

- Suppose that a scheduling algorithm favours processes that have used the least CPU time in the recent past. Why will this algorithm favour I/O-bound programs and yet not permanently starve CPU-bound programs?

Answer

- It will favour the I/O-bound programs because of their relatively short CPU burst times but, the CPU-bound programs will not starve because the I/O-bound programs will relinquish the CPU relatively often to do their I/O.

Multilevel Queue



Multilevel Queue

- Each queue has its own scheduling algorithm
  - e.g. queue of foreground processes using RR and queue of batch processes using FCFS

- Scheduling must be done between the queues
  - Fixed priority scheduling: serve all from one queue then another
    - 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 queue, 20% to background queue

Multilevel Feedback Queue

- A process can move between the various queues
  - Separates processes according to characteristics of their CPU bursts
  - **I/O-bound** processes stay in high-priority queues
  - **Compute-bound** processes relegated to lower priority queues
    - Aging can be implemented to promote very long processes and hence prevent starvation
- Parameters to be considered for a multilevel-feedback-queue scheduler:
  - How many queues?
  - Which algorithm is used for each queue?
  - How to determine when to upgrade/demote a process to a higher/lower priority?
  - How to determine which queue a process will enter?

Example

- Three queues:
  - 1) RR with time quantum of 4 milliseconds
  - 2) RR time quantum of 8 milliseconds
  - 3) FCFS

- Scheduling
  - A process at head of queue 1 gains the CPU for 4 milliseconds. If it does not finish in 4 milliseconds, it is preempted and moved to tail of queue 2
  - When queue 1 is empty, the process at the head of queue 2 gets the CPU for 8 milliseconds. If it does not finish, it is preempted and moved to queue 3
  - When queues in 1 and 2 are empty processes in queue 3 are run FCFS

Multilevel Queues

- Advantages:
  - Flexible implementation w.r.t. movement between queues
  - Enables short CPU-bound jobs to be prioritised and therefore processed quickly
  - Can be preemptive or non-preemptive

- Disadvantages:
  - Queues require monitoring, which is a costly activity

Exercise

- Suppose we have the following four processes all arriving at time 0 in the following order:

  P_1 with CPU burst of 8 milliseconds, priority 2

  P_2 with CPU burst of 2 milliseconds, priority 1

  P_3 with CPU burst of 5 millisecond, priority 3

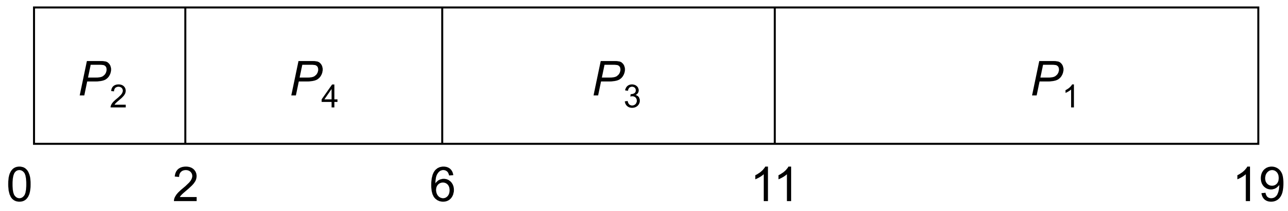
  P_4 with CPU burst of 4 milliseconds, priority 2

- Which of the following algorithms gives the minimum average waiting time: SJF, Priority, RR (using a time quantum of 2 milliseconds)?

Answer - SJF

P_1 – CPU: 8 ms, priority 2
P_2 – CPU: 2 ms, priority 1
P_3 – CPU: 5 ms, priority 3
P_4 – CPU: 4 ms, priority 2

- SJF:

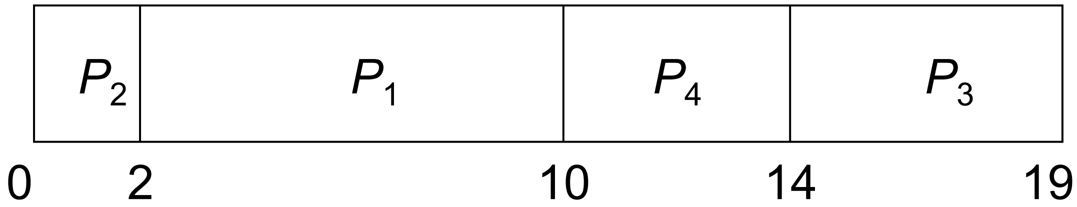


- Average waiting time is (11 + 0 + 6 + 2)/4 = 4.75 milliseconds

Answer - Priority

P_1 – CPU: 8 ms, priority 2
P_2 – CPU: 2 ms, priority 1
P_3 – CPU: 5 ms, priority 3
P_4 – CPU: 4 ms, priority 2

- Priority:



- Average waiting time is (2 + 0 + 14 + 10)/4 = 6.5 milliseconds

Answer - RR

P_1 – CPU: 8 ms, priority 2
P_2 – CPU: 2 ms, priority 1
P_3 – CPU: 5 ms, priority 3
P_4 – CPU: 4 ms, priority 2

- RR:

P_1	P_2	P_3	P_4	P_1	P_3	P_4	P_1	P_3	P_1

0 2 4 6 8 10 12 14 16 17 19

- Average waiting time is ((17-6) + 2 + (16-4) + (12-2))/4 = 8.75 milliseconds

- Thus, SJF gives the shortest average waiting time here

Scheduling Example – Windows XP

- Priorities are in range 0-31
    - Where 31 is highest priority!
- A new process is given one of the following base priorities
    - **IDLE (4)**
    - **BELOW_NORMAL (6)**
    - **NORMAL (8)**
    - **ABOVE_NORMAL (10)**
    - **HIGH (13)**
    - **REALTIME (24)**
- For NORMAL processes
    - – the foreground process (currently active window) has its time quantum lengthened
- Each process starts with a single thread, although more may be created
- Thread scheduling is handled by kernel

Windows XP Threads

- Thread priorities divided into
  - Variable class (0-15)
  - Real-time class (16-31)
- Threads also have *processor affinity*
  - CPUs may be real or virtual (hyper-threading)
- Thread queue for each priority
- Dispatcher scans queues from highest to lowest to find thread which is
  - Ready to run
  - Has affinity for CPU which is available
- If no thread found, idle thread is executed

Windows XP Scheduling

- A thread can be pre-empted if a higher-priority real-time thread becomes ready
- If time-slice of normal class thread expires, its priority is lowered
- When I/O or event wait completes for a normal class thread, priority is increased
  - Increase is greater for slow I/O (e.g. keybd)
- Thread associated with active window also gets priority increased

Linux Scheduling

- The Linux scheduler is a pre-emptive priority-based algorithm
  - Real-time tasks are distinguished from other tasks through the use of priorities
- The scheduler assigns longer time quanta to higher-priority tasks and shorter time quanta to lower-priority tasks
- When the time-slice for a task expires, it is not eligible to be run again until all other tasks have used up their time quanta
  - Priorities are dynamically recalculated when time-slice expires

Java Scheduling

- The JVM has a loosely-defined scheduling policy based on priorities
- It is possible for a lower-priority thread to continue to run even as a higher-priority thread becomes runnable, though some systems *may* support preemption
- Using time-slicing, a thread runs until either:
  - Its time quantum expires
  - It blocks for I/O
  - It exits its run() method

Java Thread Priorities

- A thread is given a default priority, between 1 and 10, when created
  - The priority will be the same as the thread that created it

- This priority remains constant unless explicitly changed by the program
  - `setPriority()` method

End of Section

- Operating systems concepts:
  - communicating sequential processes;
  - mutual exclusion, resource allocation, deadlock;
  - process management and scheduling.

- Concurrent programming in Java:
  - Java threads;
  - The Producer-Consumer problem.

- Next section: Memory Management