Announcements

- **Program #1**
  - Additional info checklist on the web page

- **Reading**
  - Chapter 6
  - Chapter 7 (Tuesday)

- **Don’t send me email from hotmail or yahoo**
  - It’s auto-deleted as SPAM
Priority Algorithms

● Fixed Queues
  – processes are statically assigned to a queue
  – sample queues: system, foreground, background

● Multilevel Feedback
  – processes are dynamically assigned to queues
  – penalize jobs that have been running longer
  – preemptive, with dynamic priority
  – have $N$ ready queues (RQ0-RQN),
    • start process in RQ0
    • if quantum expires, moved to i + 1 queue
Feedback scheduling (cont.)

– problem: turnaround time for longer processes
  • can increase greatly, even starve them, if new short jobs regularly enter system
– solution1: vary preemption times according to queue
  • processes in lower priority queues have longer time slices
– solution2: promote a process to higher priority queue
  • after it spends a certain amount of time waiting for service in its current queue, it moves up
– solution3: allocate fixed share of CPU time to jobs
  • if a process doesn’t use its share, give it to other processes
  • variation on this idea: lottery scheduling
    – assign a process “tickets” (# of tickets is share)
    – pick random number and run the process with the winning ticket.
Multilevel feedback, with
- RR within each priority queue
- 10ms second preemption
- priority based on process type and execution history, lower value is higher priority

priority recomputed once per second, and scheduler selects new process to run

For process j, \( P(i) = \text{Base} + \frac{\text{CPU}(i-1)}{2} + \text{nice} \)
- \( P(i) \) is priority of process \( j \) at interval \( i \)
- \( \text{Base} \) is base priority of process \( j \)
- \( \text{CPU}(i) = \frac{\text{U}(i)}{2} + \frac{\text{CPU}(i-1)}{2} \)
  - \( \text{U}(i) \) is CPU use of process \( j \) in interval \( i \)
  - exponentially weighted average CPU use of process \( j \) through interval \( i \)
- \( \text{nice} \) is user-controllable adjustment factor
UNIX (cont.)

- Base priority divides all processes into (non-overlapping) fixed bands of decreasing priority levels
  - swapper, block I/O device control, file manipulation, character I/O device control, user processes
- bands optimize access to block devices (disk), allow OS to respond quickly to system calls
- penalizes CPU-bound processes w.r.t. I/O bound
- targets general-purpose time sharing environment
Windows NT

- **Target:**
  - single user, in highly interactive environment
  - a server
- preemptive scheduler with multiple priority levels
- flexible system of priorities, RR within each, plus dynamic variation on basis of current thread activity for *some* levels
- 2 priority bands, real-time and variable, each with 16 levels
  - real-time ones have higher priority, since require immediate attention (e.g. communication, real-time task)
In real-time class, all threads have fixed priority that never changes

In variable class, priority begins at an initial value, and can change, up or down
  - FIFO queue at each level, but thread can switch queues

Dynamic priority for a thread can be from 2 to 15
  - if thread interrupted because time slice is up, priority lowered
  - if interrupted to wait on I/O event, priority raised
  - favors I/O-bound over CPU-bound threads
  - for I/O bound threads, priority raised more for interactive waits (e.g. keyboard, display) than for other I/O (e.g. disk)
Cooperating Processes

- Often need to share information between processes
  - information: a shared file
  - computational speedup:
    - break the problem into several tasks that can be run on different processors
    - requires several processors to actually get speedup
  - modularity: separate processes for different functions
    - compiler driver, compiler, assembler, linker
  - convenience:
    - editing, printing, and compiling all at once
Interprocess Communication

- Communicating processes establish a link
  - can more than two processes use a link?
  - are links one way or two way?
  - how to establish a link
    - how do processes name other processes to talk to
      - use the process id (signals work this way)
      - use a name in the filesystem (UNIX domain sockets)
      - indirectly via mailboxes (a separate object)

- Use send/receive functions to communicate
  - send(dest, message)
  - receive(dest, message)
Producer-consumer pair

- producer creates data and sends it to the consumer
- consumer reads the data and uses it
- examples: compiler and assembler can be used as a producer-consumer pair
- Buffering
  - processes may not produce and consume items one by one
  - need a place to store produced items for the consumer
    - called a buffer
  - could be fixed size (bounded buffer) or unlimited (unbounded buffer)
Message Passing

- **What happens when a message is sent?**
  - sender blocks waiting for receiver to receive
  - sender blocks until the message is on the wire
  - sender blocks until the OS has a copy of the message
  - sender blocks until the receiver responds to the message
    - sort of like a procedure call
    - could be expanded into a remote procedure call (RPC) system

- **Error cases**
  - a process terminates:
    - receiver could wait forever
    - sender could wait or continue (depending on semantics)
  - a message is lost in transit
    - who detects this? could be OS or the applications

- **Special case: if 2 messages are buffered, drop the older one**
  - useful for real-time info systems