Slide 1

Administrivia

- Midterm will be 10/22. Quiz 2 will be this coming Monday.
- Next homework coming soon.

Slide 2

Scheduling Algorithms — Review/Recap

- Purpose of a scheduling algorithm is to decide which process to run next.
- Many of them, ranging from simple to not-so-simple . . .

Slide 3

First Come, First Served (FCFS)

- Basic ideas:
  - Keep a (FIFO) queue of ready processes.
  - When a process starts or becomes unblocked, add it to the end of the queue.
  - Switch when the running process exits or blocks. (I.e., no preemption.)
  - Next process is the one at the head of the queue.
- Points to consider:
  - How difficult is this to understand, implement?
  - What happens if a process is CPU-bound?
  - Would this work for an interactive system?

Slide 4

Shortest Job First (SJF)

- Basic ideas:
  - Assume work is in the form of “jobs” with known running time, no blocking.
  - Keep a queue of these jobs.
  - When a process (job) starts, add it to the queue.
  - Switch when the running process exits (i.e., no preemption).
  - Next process is the one with the shortest running time.
- Points to consider:
  - How difficult is this to understand, implement?
  - What if we don’t know running time in advance?
  - What if all jobs are not known at the start?
  - Would this work for an interactive system?
  - What’s the key advantage of this algorithm?

Slide 5

Round-Robin Scheduling

- Basic ideas:
  - Keep a queue of ready processes, as before.
  - Define a "time slice" — maximum time a process can run at a time.
  - When a process starts or becomes unblocked, add it to the end of the queue.
  - Switch when the running process uses up its time slice, or it exits or blocks. (I.e., preemption allowed!)
  - Next process is the one at the head of the queue.
- Points to consider:
  - How difficult is this to understand, implement?
  - Would this work for an interactive system?
  - How do you choose the time slice?

Slide 6

Priority Scheduling

- Basic ideas:
  - Keep a queue of ready processes, as before.
  - Assign a priority to each process.
  - When a process starts or becomes unblocked, add it to the end of the queue.
  - Switch when the running process exits or blocks, or possibly when a process starts. (I.e., preemption may be allowed.)
  - Next process is the one with the highest priority.
- Points to consider:
  - What happens to low-priority processes? (So, maybe we should change priorities sometimes?)
  - How do we decide priorities? (external considerations versus internal characteristics)

Slide 7

Shortest Remaining Time Next

- Basic idea — variant on SJF:
  - Assume that for each process (job), we know how much longer it will take.
  - Keep a queue of ready processes, as before; add to it as before.
  - Switch when the running process exits *or* a new process starts. (I.e., preemption allowed — requires recomputing time left for preempted process.)
  - Next process is the one with the shortest time left.
- Points to consider:
  - How does this compare with SJF?

Slide 8

Multiple-Queue Scheduling

- Basic idea — variant on priority scheduling:
  - Divide processes into "priority classes".
  - When picking a new process, pick one from the highest-priority class with ready processes.
  - Within a class, use some other algorithm to decide (round-robin, e.g.).
  - Optionally, periodically lower processes' priorities.

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Some Other Scheduling Algorithms

- Guaranteed scheduling.

  "Guarantee" each process (of N) 1/N of the CPU cycles; (try to) schedule to make this true.

  Calculate, for each process, fraction of the time it has had the CPU in its lifetime, fraction it "should" have had; choose process for which actual time / entitled time is smallest.

- Lottery scheduling.

  Give each process one or more "lottery tickets" — more or fewer depending on its priority (so to speak); pick one at random to decide who's next.

- Fair-share scheduling.

  Factor in process's owner in deciding which process to pick. I.e., if two "equal" users, schedule processes such that user A's processes get about as much time as those of user B.

Slide 10

Scheduling in Real-Time Systems

- "Real-time system" — system in which events must ("hard real time") or should ("soft real time") be handled by some deadline. Often events to be handled are periodic, and we know how often they arrive and how long they take to process.
- Role of scheduler in such systems could be critical.
- An interesting question — sometimes getting everything scheduled on time is impossible (example?). If we know periodicity and time-to-handle of all types of events, can we decide this? (Yes — general formula in textbook; can be interesting to work through details.)
- Complex topic; see chapter 7 for more info.

Slide 11

Scheduling and Threads

- If system uses both processes and threads, we now possibly have an additional level of scheduling.
- Details depend on whether threads are implemented in user space or kernel space:
  - In user space — runtime system that manages them must do scheduling, and without the benefit of timer interrupts.
  - In kernel space — scheduling done at o/s level, so context switches are more expensive, but timer interrupts are possible, etc.

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What Do Real Systems Use?

- Traditional UNIX: two-level approach (upper level to swap processes in/out of memory, lower level for CPU scheduling), using multiple-queue scheduling for CPU scheduling. See chapter 10 for details.
- Linux: facilities for soft real-time scheduling and "timesharing" scheduling, with the latter a mix of priority and round-robin scheduling. See chapter 10 for details. As of kernel version 2.6.23, replaced with "Completely Fair Scheduler", which sounds like what Tanenbaum calls "guaranteed scheduling".
- Windows NT/2000/Vista: multiple-queue scheduling of threads, with round-robin for each queue.
- MVS (IBM mainframe): three-level scheme with lots of options for administrator(s) to define complex policies.

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One More Scheduling-Related Topic

- A question I used to use as homework:

  Recall that some proposed solutions to the mutual-exclusion problem (e.g., Peterson's algorithm) involve busy waiting. Do such solutions work if priority scheduling is being used and one of the processes involved has higher priority than the other(s)? Why or why not? How about if round-robin scheduling is being used? Why or why not? Notice that a process can be interrupted while in its critical region; if that happens, it is considered to still be in its critical region, and other processes wanting to be in their critical regions are supposed to busy-wait.

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One More Scheduling-Related Topic, Continued

- Yes, with priority scheduling, a solution involving busy-waiting can fail ("priority inversion", in text). Not so with round-robin.

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Sidebar — Simulating Scheduling Algorithms

- Can be helpful in understanding how these algorithms work to simulate what they do given a particular sequence of inputs.
- Example — batch system with the following jobs.

job ID	running time	arrival time
A	6	0
B	4	0
C	10	0
D	2	2

Asked to compute turnaround times for all jobs using FCFS, what would you do . . .

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Recap — Scheduling Algorithms

- Main idea — decide which process to run next (when running process exits, becomes blocked, or is interrupted).
- Many possibilities, ranging from simple to complex. Real systems seem to use hybrid strategies.
- How to choose one?
  - Be clear on goals.
  - Maybe evaluate some possibilities to see which one(s) meet goals — analytic or experimental evaluation.
  - Build in some tuning knobs — “separate policy from mechanism”.

Slide 17

Minute Essay

- Suppose you have a batch system with the following jobs.

job ID	running time	arrival time
A	6	0
B	4	0
C	10	0
D	2	2

Compute turnaround times for all jobs using SJF.

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Minute Essay Answer

- Solution:

job ID	start time	stop time	turnaround time (SJF)
A	6	12	12
B	0	4	4
C	12	22	22
D	4	6	4