Scheduling

CSE 410 - Computer Systems
November 19, 2001
Readings and References

• Reading
  › Chapter 6, Sections 6.1 through 6.5, and section 6.7.2, *Operating System Concepts*, Silberschatz, Galvin, and Gagne

• Other References
Process State

- A process can be in one of several states
  - new, ready, running, waiting, terminated
- The OS keeps track of process state by maintaining a queue of PCBs for each state
- The **ready queue** contains PCBs of processes that are waiting to be assigned to the CPU
Windows 2000 Thread States

7 - Unknown
6 - Transition
5 - Wait (for something to complete)
4 - Terminated
3 - Standby (on-deck circle)
2 - Running (at bat)
1 - Ready (eligible to be selected)
0 - Initialized
The Scheduling Problem

- Need to share the CPU between multiple processes in the ready queue
  - OS decides which process gets the CPU next
  - Once a process is selected, OS does some work to get the process running on the CPU
How Scheduling Works

- The short-term scheduler is responsible for choosing a process from the ready queue.
- The scheduling algorithm implemented by this module determines how process selection is done.
- The scheduler hands the selected process off to the dispatcher which gives the process control of the CPU.
Scheduling Decisions - When?

- Scheduling decisions are always made:
  - when a task is terminated
  - when a task switches from running to waiting
- Scheduling decisions are also made when an interrupt occurs in a preemptive system
Scheduling Decisions - Why?

• Maximize throughput and resource utilization
  › Need to overlap CPU and I/O activities.
• Minimize response time, waiting time and turnaround time
• Share CPU in a “fair” way
• Conflicting constraints
  › constantly need to make tradeoffs
Non-preemptive scheduling

- Non-preemptive scheduling
  - The scheduler waits for a running task to voluntarily relinquish the CPU (task either terminates or blocks)
- Simplifies kernel
- Simplifies hardware
- But it also makes it difficult to manage the system’s performance effectively
Preemptive scheduling

- Preemptive scheduling
  - The OS can force a running task to give up control of the CPU, allowing the scheduler to pick another task
  - OS gains control on a regular interrupt schedule
- A little more overhead
- But allows much better control of the overall system performance
Non-preemptive/Preemptive

- **Non-preemptive** scheduling
  - The task decides when it stops
  - The scheduler must wait for a running task to voluntarily relinquish the CPU
  - Used in the past, now only in real-time systems

- **Preemptive** scheduling
  - OS can force a running task to give up control of the CPU and pick another task to run
  - Used by all major OS's today
CPU and I/O Bursts

• Typical process execution pattern:
  › use the CPU for a while (CPU burst)
  › then do some I/O operations (I/O burst)

• CPU bound processes have long CPU bursts and perform I/O operations infrequently

• I/O bound processes spend most of their time doing I/O and have short CPU bursts
First Come First Served

- Scheduler selects the process at the head of the ready queue; typically non-preemptive
- Example: 3 processes arrive at the ready queue in the following order:
  
  P1 (CPU burst = 240 ms), P2 (CPU burst = 30 ms),
  P3 (CPU burst = 30 ms)

+ Simple to implement
- Average waiting time can be large
Round Robin

- FCFS + preemptive scheduling
- Ready queue is a circular queue
- Each process gets the CPU for a time quantum (a time slice), typically 10 - 100 ms
- A task runs until it uses up its time slice or blocks
Round Robin Examples

- Short jobs don’t get stuck behind long jobs

- Average response time for jobs of same length is bad

FCFS:

RR:
Round Robin Pros and Cons

+ Works well for short jobs; typically used in timesharing systems
- High overhead due to frequent context switches
- Increases average waiting time, especially if CPU bursts are the same length and need more than one time quantum
Priority Scheduling

- Select the process with the highest priority
- Priority is based on some attribute of the process (e.g., memory requirements, owner of process, etc.)
- Starvation problem
  - low priority jobs may wait indefinitely
  - can prevent starvation by aging (increase process priority as it waits)
Priority Inversion

- Three tasks with priorities: HI, MED, LOW
- Suppose LOW locks resource that HI needs
  - LOW prevents HI from running
  - MED prevents LOW from running
  - HI can’t run until MED finishes and LOW unlocks
- This is known as priority inversion
- Solution: increase priority of a process holding a lock to the max priority of a process waiting on the lock
  - LOW -> LOW until it releases the lock
Shortest Job First

• Special case of priority scheduling
  › priority = expected length of CPU burst
• Scheduler chooses the process with the shortest remaining time to completion
  › think about waiting at the copy machine
• Example: What’s the average waiting time?

30 30 240
Shortest Job First Pros and Cons

+ It’s the best you can do to minimize average response time
  › can prove the algorithm is optimal

- Difficult to predict the future
  › Use past behavior of the task to predict length of its next CPU burst

- Unfair-- possible starvation
  › many short jobs can stall long jobs
An Aside: Exponential Average

- \(0 \leq \alpha \leq 1\)
- \(T_{n+1} = \alpha \cdot t_n + (1 - \alpha) \cdot T_n\)
- \(T_{n+1} = T_n + \alpha \cdot (t_n - T_n)\)
- \(\text{value}_{n+1} = \text{value}_n + \alpha \cdot (\text{target} - \text{value}_n)\)
- etc, etc
Multi-level Queues

- Maintain multiple ready queues based on task “type” (e.g., system, interactive, batch)
- Each task is assigned to a particular queue
  - Each queue has a priority
  - May use a different scheduling algorithm in each queue
  - There are policies implicit in these choices
- Also need to schedule between queues
Multi-level Feedback Queues

- Adaptive algorithm: task priority changes based on past behavior
- Task starts with high priority
  - because it’s probably a short job
- Decrease priority of tasks that hog the CPU (CPU-bound jobs)
- Increase priority of tasks that don’t use the CPU much (I/O-bound jobs)