CS 3204
Operating Systems

Lecture 17

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Announcements

- Project 1 is due Feb 27, 11:59pm
  - 3 days left
  - priority donation: extra credit for handling & testing donation + priority change
- Office hours today 4-5 F
- Next week: Project 2 Help Sessions Wed Mar 1 & Th Mar 2 from 7 to 9pm in MCB 126
- Reading assignments:
  - Stallings Chapter 9.1-9.4, plus will post additional reading over the weekend

Scheduling

Resource Allocation & Scheduling

- Resource management is primary OS function
- Involves resource allocation & scheduling
  - Who gets to use what resource and for how long
- Resources we consider now
  - CPU time
  - Disk bandwidth
  - Network bandwidth
  - RAM
  - Disk space
- Processes are the principals that use resources
  - often on behalf of users

CPU vs. Other Resources

- CPU is not the only resource that needs to be scheduled
- Overall system performance depends on efficient use of all resources
  - Resource can be in use (busy) or be unused (idle)
    - Duty cycle: portion of time busy
  - Consider I/O device: busy after receiving I/O request – if CPU scheduler delays process that will issue I/O request, I/O device is underutilized
- Ideal: want to keep *all* devices busy

Preemptible vs Nonpreemptible Resources

- Nonpreemptible resources:
  - Once allocated, can't easily ask for them back – must wait until process returns them (or exits)
    - Examples: Locks, Disk Space, Control of terminal
- Preemptible resources:
  - Can be taken away ("preempted") and returned without the process noticing it
    - Examples: CPU, Memory

Physical vs Virtual Memory

- Classification of a resource as preemptible depends on price one is willing to pay to preempt it
  - Can theoretically preempt most resources via copying & indirection
- Virtual Memory: mechanism to make physical memory preemptible
  - Take away by swapping to disk, return by reading from disk (possibly swapping out others)
- Not always tolerable
  - resident portions of kernel
  - Pintos kernel stack pages

Space Sharing vs Time Sharing

- Space Sharing: *Allocation ("how much?")*
  - Use if resource can be split (multiple CPUs, memory, etc.)
  - Use if resource is non-preemptible
- Time Sharing: *Scheduling ("how long?")*
  - Use if resource can't be split
  - Use if resource is easily preemptible

CPU Scheduling Terminology (1)

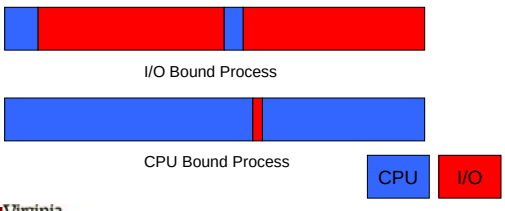
- A job (sometimes called a task, or a job instance)
  - Activity that's scheduled: process or part of a process
- Arrival time: time when job arrives
- Start time: time when job actually starts
- Finish time: time when job is done
- Completion time (aka Turn-around time)
  - Finish time – Arrival time
- Response time
  - Time when user sees response – Arrival time
- Execution time (aka cost): time a job need to execute

Static vs Dynamic Scheduling

- Static
  - All jobs, their arrival & execution times are known in advance, create a schedule, execute it
    - Used in statically configured systems, such as embedded real-time systems
- Dynamic or Online Scheduling
  - Jobs are not known in advance, scheduler must make online decision whenever jobs arrives or leaves
    - Execution time may or may not be known
    - Behavior can be modeled by making assumptions about nature of arrival process

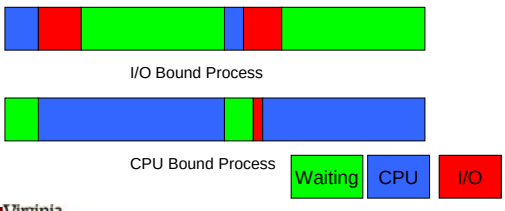
CPU Scheduling Model

- Process alternates between CPU burst & I/O burst



CPU Scheduling Model (2)

- If these were executed on the same CPU:

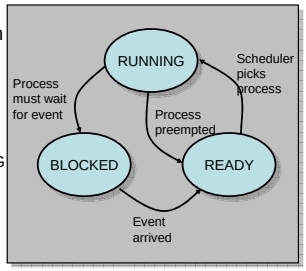


CPU Scheduling Terminology (2)

- Waiting time = time when job was ready-to-run
  - didn't run because CPU scheduler picked another job
- Blocked time = time when job was blocked
  - while I/O device is in use
- Completion time
  - Execution time + Waiting time + Blocked time

Preemptive vs Nonpreemptive Scheduling

- Q.: when is scheduler asked to pick a thread from ready queue?
- Nonpreemptive:
  - Only when RUNNING→ BLOCKED transition
  - Or RUNNING → EXIT
  - Or voluntary yield: RUNNING → READY
- Preemptive
  - Also when BLOCKED→ READY transition
  - Also on timer



CPU Scheduling Goals

- Minimize latency
  - Can mean (avg) completion time
  - Can mean (avg) response time
- Maximize throughput
  - Throughput: number of finished jobs per time-unit
  - Implies minimizing overhead (for context-switching, for scheduling algorithm itself)
  - Requires efficient use of non-CPU resources
- Fairness
  - Minimize variance in waiting time/completion time

Scheduling Constraints

- Reaching those goals is difficult, because
  - Goals are conflicting:
    - Latency vs. throughput
    - Fairness vs. low overhead
  - Scheduler must operate with incomplete knowledge
    - Execution time may not be known
    - I/O device use may not be known
  - Scheduler must make decision fast
    - Approximate best solution from huge solution space

First Come First Serve

- Schedule processes in the order in which they arrive
  - Run until completion (or until they block)
- Simple!
- Example:

Q.: what is the average completion time?

FCFS (cont'd)

- Disadvantage: completion time depends on arrival order
  - Unfair to short jobs
- Possible Convoy Effect:
  - 1 CPU bound (long CPU bursts, infrequent I/O bursts), multiple I/O bound jobs (frequent I/O bursts, short CPU bursts).
  - CPU bound process monopolizes CPU: I/O devices are idle
  - New I/O requests by I/O bound jobs are only issued when CPU bound job blocks – CPU bound job "leads" convoy of I/O bound processes
- FCFS not usually used for CPU scheduling, but often used for other resources (network device)

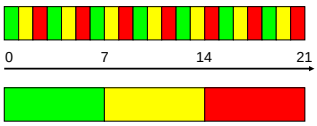
Round-Robin

- Run process for a timeslice (quantum), then move on to next process, repeat
- Decreases avg completion if jobs are of different lengths
- No more unfairness to short jobs!

Q.: what is the average completion time?

Round Robin (2)

- What if there are no "short" jobs?



Q.: what is the average completion time?

What would it be under FCFS?

Round Robin – Cost of Time Slicing

- Context switching incurs a cost
  - Direct cost (execute scheduler & context switch) + indirect cost (cache & TLB misses)
- Long time slices → lower overhead, but approaches FCFS if processes finish before timeslice expires
- Short time slices → lots of context switches, high overhead
- Typical cost: context switch < 1ms
- Time slice typical around 100ms
  - Linux: 100ms default, adjust to between 10ms & 300ms
- Note: time slice length != interval between timer interrupts (as you know from Pintos…)
  - Timer frequency usually 1000Hz

Shortest Process Next (SPN)

- Idea: remove unfairness towards short processes by always picking the shortest job
- If done nonpreemptively also known as:
  - Shortest Job First (SJF), Shortest Time to Completion First (STCF)
- If done preemptively known as:
  - Shortest Remaining Time (SRT), Shortest Remaining Time to Completion First (SRTCF)

SPN (cont'd)

- Provably optimal with respect to completion time:
  - Moving shorter job up reduces its completion time more than it delays completion of longer job that follows
- Advantage: Good I/O utilization
- Disadvantage:
  - Can starve long jobs

Big Q: How do we know the length of a job?

Practical SPN

- Usually don't know (remaining) execution time
  - Exception: profiled code in real-time system; or worst-case execution time analysis (WCET)
- Idea: determine future from past:
  - Assume next CPU burst will be as long as previous CPU burst
  - Or: weigh history using (potentially exponential) average: more recent burst lengths more predictive than past CPU bursts
- Note: for some resources, we know or can compute length of next "job":
  - Example: disk scheduling (shortest-seek time first)