Operating System

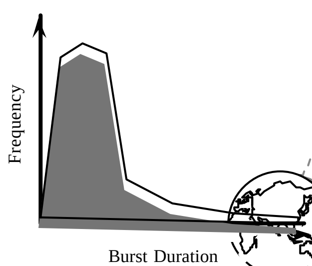
Process Scheduling
(Ch 4.2, 5.1 - 5.3)

Schedulers

- Short-Term
  - "Which process gets the CPU?"
  - Fast, since once per 100 ms
- Long-Term (batch)
  - "Which process gets the Ready Queue?"
- Medium-Term (Unix)
  - "Which Ready Queue process to memory?"
  - Swapping

CPU-IO Burst Cycle

`add`
`read`
(I/O Wait)
`store`
`increment`
`write`
(I/O Wait)



Preemptive Scheduling

- Four times to re-schedule
  1 Running to Waiting (I/O wait)
  2 Running to Ready (time slice)
  3 Waiting to Ready (I/O completion)
  4 Termination
- #2 optional ==> "Preemptive"
- Timing may cause unexpected results
  - updating shared variable
  - kernel saving state

Question

- What Performance Criteria Should the Scheduler Seek to Optimize?
  - Ex: CPU minimize time spent in queue
  - Others?

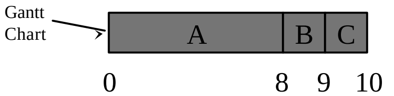
Scheduling Criteria

1 CPU utilization (40 to 90)
2 Throughput (processes / hour)
3 Turn-around time
4 Waiting time (in queue)

- Maximize #1, #2   Minimize #3, #4
- Response time
  - Self-regulated by users (go home)
  - Bounded ==> Variance!

First-Come, First-Served

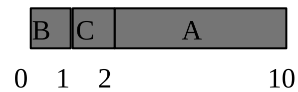
Process	Burst Time
A	8
B	1
C	1



- Avg Wait Time (0 + 8 + 9) / 3 = 5.7

Shortest Job First

Process	Burst Time
A	8
B	1
C	1

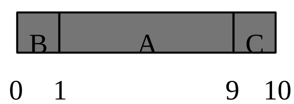


- Avg Wait Time (0 + 1 + 2) / 3 = 1
- Optimal Avg Wait
- Prediction tough … Ideas?

Priority Scheduling

- SJF is a special case

Process	Burst Time	Priority
A	8	2
B	1	1
C	1	3



- Avg Wait Time (0 + 1 + 9) / 3 = 3.3

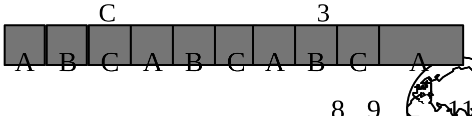
Priority Scheduling Criteria?

- Internal
  - open files
  - memory requirements
  - *CPU time used* - *time slice expired (RR)*
  - *process age* - *I/O wait completed*
- External
  - $
  - department sponsoring work
  - *process importance*
  - *super-user (root)* - *nice*

Round Robin

- Fixed time-slice and Preemption

Process	Burst Time
A	5
B	3
C	3



- Avg = (8 + 9 + 11) / 3 = 9.3
- FCFS? SJF?

Round Robin Fun

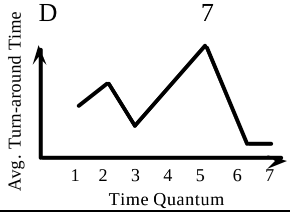
Process	Burst Time
A	10
B	10
C	10

- Turn-around time?
  - q = 10
  - q = 1
  - q --> 0

More Round Robin Fun

Process	Burst Time
A	6
B	3
C	1
D	7

Rule:
80% within
one quantum



Fun with Scheduling

Process	Burst Time	Priority
A	10	2
B	1	1
C	2	3

- Gantt Charts:
  - FCFS
  - SJF
  - Priority
  - RR (q=1)
- Performance:
  - Throughput
  - Waiting time
  - Turnaround time

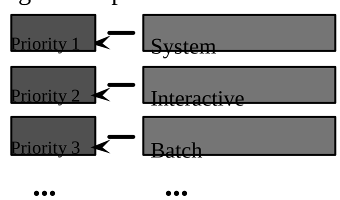
More Fun with Scheduling

Process	Arrival Time	Burst Time
A	0.0	8
B	0.4	4
C	1.0	1

- Turn around time:
  - FCFS
  - SJF
  - q=1 CPU idle
  - q=0.5 CPU idle

Multi-Level Queues

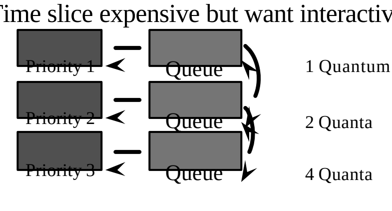
- Categories of processes



- Run all in 1 first, then 2 …
- Starvation!
- Divide between queues: 70% 1, 15% 2 …

Multi-Level Feedback Queues

- Time slice expensive but want interactive



- Consider process needing 100 quanta
  - 1, 4, 8, 16, 32, 64 = 7 swaps!
- Favor interactive users

Evaluating Scheduling Algorithms

- With all these possible scheduling algorithms, how to choose one?
  - Ease of implementation
  - Efficiency of implementation / low overhead
  - Performance evaluation (next slide)

Performance Evaluation Methods

- Deterministic methods / Gantt charts
  - Use more realistic workloads
- Queueing theory
  - Mathematical techniques
  - Uses probablistic models of jobs / CPU utilization
- Simulation
  - Probabilistic or trace-driven

Linux Process Scheduling

- Two classes of processes:
  - Real-Time
  - Normal
- Real-Time:
  - Always run Real-Time above Normal
  - Round-Robin or FIFO
  - "Soft" not "Hard"

Linux Process Scheduling

- Normal: *Credit-Based*
  - process with most credits is selected
  - time-slice then lose a credit (0, then suspend)
  - no runnable process (all suspended), add to *every* process:

    `credits = credits/2 + priority`
- Automatically favors I/O bound processes

Questions

- What is a PCB?
- List steps that occur during *interrupt*
- Explain how SJF works
- True or False:
  - FCFS is optimal in terms of avg waiting time
  - Most processes are CPU bound
  - The shorter the time quantum, the better
- `micro-shell.c`?

Interrupt Handling

- Stores program counter (hardware)
- Loads new program counter (hardware)
  - jump to interrupt service procedure
- Save PCB information (assembly)
- Set up new stack (assembly)
- Set "*waiting*" process to "*ready*" (C)
- Re-schedule (probably awakened process) (C)
  - "`dispatcher`" in SOS, "`schedule`" in Linux
- If new process, called a *context-switch*

Outline

- Processes ✓
  - PCB ✓
  - Interrupt Handlers ✓
- Scheduling
  - Algorithms ✓
  - Linux
  - WinNT ¬

Windows NT Scheduling

- Basic scheduling unit is a thread
- Priority based scheduling per thread
- Preemptive operating system
- No shortest job first, no quotas

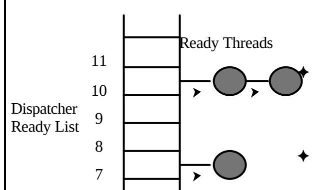
Priority Assignment

- NT kernel uses 31 priority levels
  - 31 is the highest; 0 is system idle thread
  - Realtime priorities: 16 - 31
  - Dynamic priorities: 1 - 15
- Users specify a *priority class*:
    - realtime (24) , high (13), normal (8) and idle (4)
  - and a relative priority:
    - highest (+2), above normal (+1), normal (0), below normal (-1), and lowest (-2)
  - to establish the *starting priority*
- Threads also have a *current priority*

Quantum

- Determines how long a Thread runs once selected
- Varies based on:
  - NT Workstation or NT Server
  - Intel or Alpha hardware
  - Foreground/Background application threads
- *How do you think it varies with each?*

Dispatcher Ready List



- Keeps track of all Ready-to-execute threads
- Queue of threads assigned to each level

FindReadyThread

- Locates the highest priority thread that is ready to execute
- Scans dispatcher ready list
- Picks front thread in highest priority nonempty queue
- *When is this like round robin?*

Boosting and Decay

- Boost priority
  - Event that "wakes" blocked thread
  - Boosts never exceed priority 15 for *dynamic*
  - *Realtime* priorities are not boosted
- Decay priority
  - by one for each quantum
  - decays only to starting priority (no lower)

Starvation Prevention

- Low priority threads may never execute
- "Anti-CPU starvation policy"
  - thread that has not executed for 3 seconds
  - boost priority to 15
  - double quantum
- Decay is swift not gradual after this boost