Interactive Scheduling

Two Level Scheduling
- Interactive systems commonly employ two-level scheduling
  - CPU scheduler and Memory Scheduler
  - Memory scheduler was covered in VM
  - We will focus on CPU scheduling

Round Robin Scheduling
- Each process is given a timeslice to run in
- When the timeslice expires, the next process preempts the current process, and runs for its timeslice, and so on
- Implemented
  - A ready queue
  - A regular timer interrupt

Our Earlier Example
- 5 Process
  - Process 1 arrives slightly before process 2, etc...
  - All are immediately runnable
  - Execution times indicated by scale on x-axis

Round Robin Schedule

Round Robin Schedule
### Round Robin

- **Pros**
  - Fair, easy to implement

- **Con**
  - Assumes everybody is equal

- **Issue:** What should the timeslice be?
  - Too short
    - Waste a lot of time switching between processes
    - Example: timeslice of 4ms with 1 ms context switch = 20% round robin overhead
  - Too long
    - System is not responsive
    - Example: timeslice of 100ms
      - If 10 people hit “enter” key simultaneously, the last guy to run will only see progress after 1 second.
    - Degenerates into FCFS if timeslice longer than burst length

### Priorities

- Each Process (or thread) is associated with a priority
- Provides basic mechanism to influence a scheduler decision:
  - Scheduler will always chooses a thread of higher priority over lower priority
- Priorities can be defined internally or externally
  - Internal: e.g. I/O bound or CPU bound
  - External: e.g. based on importance to the user

### Example

- 5 Jobs
  - Job number equals priority
  - Priority 1 > priority 5
  - Release and execution times as shown
  - Priority-driven preemptively scheduled
Priorities

- Usually implemented by multiple priority queues, with round robin on each queue
- Con
  - Low priorities can starve
  - Need to adapt priorities periodically
    - Based on ageing or execution history

Traditional UNIX Scheduler

- Two-level scheduler
  - High-level scheduler schedules processes between memory and disk
  - Low-level scheduler is CPU scheduler
    - Based on a multi-level queue structure with round robin at each level

Traditional UNIX Scheduler

- The highest priority (lower number) is scheduled
- Priorities are re-calculated once per second, and re-inserted in appropriate queue
  - Avoid starvation of low priority threads
  - Penalise CPU-bound threads

Traditional UNIX Scheduler

- Priority = CPU_usage +nice +base
  - CPU_usage = number of clock ticks
  - Nice is a value given to the process by a user to permanently boost or reduce its priority
  - Base is a set of hardwired, negative values used to boost priority of I/O bound system activities
    - Swapper, disk I/O, Character I/O

Some Issues with Priorities

- Require adaption over time to avoid starvation (not considering hard real-time which relies on strict priorities).
- Adaption is:
  - usually ad-hoc,
    - hence poorly understood, and unpredictable
  - Gradual, hence unresponsive
- Difficult to guarantee a desired share of the CPU
- No way for applications to trade CPU time

Lottery Scheduling

- Each process is issued with “lottery tickets” which represent the right to use/consume a resource
  - Example: CPU time
- Access to a resource is via “drawing” a lottery winner.
  - The more tickets a process possesses, the higher chance the process has of winning.
Lottery Scheduling

- Advantages
  - Simple to implement
  - Highly responsive (can reallocate tickets held)
  - Tickets can be traded to implement individual scheduling policy between co-operating threads

Example Lottery Scheduling

- Four process running concurrently
  - Process A: 15% CPU
  - Process B: 25% CPU
  - Process C: 5% CPU
  - Process D: 55% CPU

  - How many tickets should be issued to each?

Fair-Share Scheduling

- So far we have treated processes as individuals
- Assume two users
  - One user has 1 process
  - Second user has 9 processes
  - The second user gets 90% of the CPU
  - Some schedulers consider the owner of the process in determining which process to schedule
    - E.g., for the above example we could schedule the first user’s process 9 times more often than the second user’s processes
  - Many possibilities exist to determine a fair schedule
    - E.g. Appropriate allocation of tickets in lottery scheduler

Lottery Scheduling Performance

Observed performance of two processes with varying ratios of tickets

![Graph showing observed performance of lottery scheduling](image)