CPU Scheduling

ECE595
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Y. Charlie Hu

Roadmap So Far

- Processes, (threads), creation
- Inter-process comm by sharing data → process synchronization
  - OS-provided sync. Primitives
    - Mutual exclusion & Critical section
    - Semaphore (binary semaphore)
    - Lock / condition variable
  - Classic sync. Problems
    - Producer-consumer problem
    - Reads-writers problem
    - Dining Philosophers problem (deadlock)
  - Semaphore implementation in OS
  - Wait-free synchronization
- Inter-process comm by messaging (mailboxes)

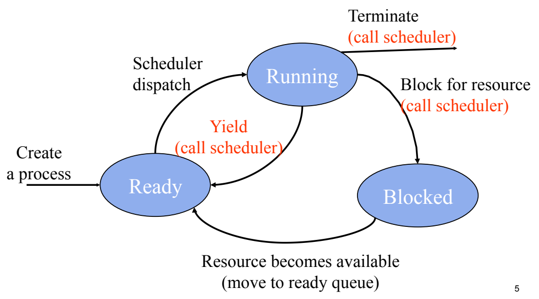
CPU Scheduling

- CPU scheduling is the basis of multiprogrammed operating systems
- By switching the CPU among processes, the OS can make the CPU/computer maximally utilized

Hardware Support

- Without hardware support, can we do anything other than non-preemptive scheduling?

[lec3] Process State Transition of Non-Preemptive Scheduling

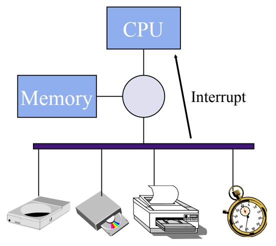


Timesharing Systems

- Timesharing systems support interactive use
  - each user feels he/she has the entire machine
- How?
  - optimize response time
  - based on time-slicing

Timer Interrupts

- Using timer interrupt to do CPU management
- Timer interrupt
  - generated by hardware
  - setting requires privilege
  - delivered to the OS



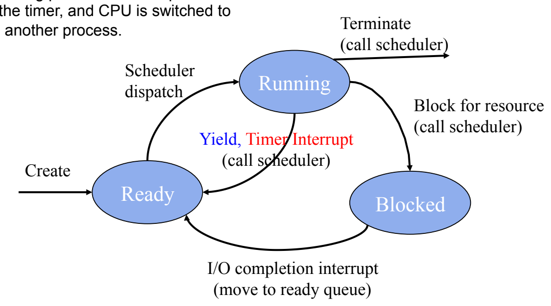
Using Interrupts For Scheduling

Basic idea

- before moving process to running, OS sets timer
- if process yields/blocks, clear timer, go to scheduler
- If timer expires, go to scheduler

Preemptive Scheduling

A running process is interrupted by the timer, and CPU is switched to run another process.



[lec4] *Context Switch*

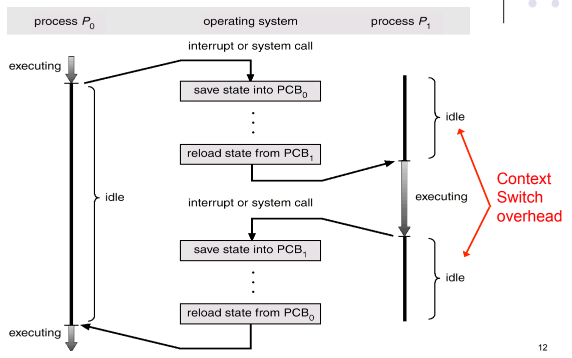
- Definition:
  switching the CPU to another process, which involves saving the state of the old process and loading the state of the new process

- What state?
- Where to store them?

Process Control Block (Process Table)

- Process management info
  - State (ready, running, blocked)
  - PC & Registers, parents, etc
  - CPU scheduling info (priorities, etc.)
- Memory management info
  - Segments, page table, stats, etc
- I/O and file management
  - Communication ports, directories, file descriptors, etc.

Context Switch



Preemptive Scheduling Considerations

- Timer granularity
  - Finer timers = more responsive
  - Coarser timers = more efficient
- CPU Accounting (CPU running stats)
  - Used by the scheduler
  - Useful for the programmer

OS as a Resource Manager: Allocation vs. Scheduling

- Allocation (spatial)
  - Who gets what. Given a set of requests for resources (e.g. memory), which processes should be given which resources (e.g. how much memory & where) for best utilization
- Scheduling (temporal)
  - How long can they keep it. When more resources (e.g. 10 CPUs) are requested than can be granted (e.g. 1 CPU), in what order can they be serviced?

[lec1] Separating Policy from Mechanism

Mechanism – tool to achieve some effect

Policy – decisions on how to use tool
examples:
- All users treated equally
- All program instances treated equally
- Preferred users treated better

Separation leads to flexibility

Preemptive CPU Scheduling

- What is in it?
  - Mechanism + policy
  - Mechanisms fairly simple
  - Policy choices harder

[lec1] Brief History of Computer Systems (1)

- In the beginning, 1 user/program at a time
- Simple batch systems were 1st real OS
  - Spooling and buffering allowed jobs to be read ahead of time
- Multiprogramming systems provided increased utilization (throughput)
  - multiple runable jobs loaded in memory
  - overlap I/O with computation
  - benefit from asynchronous I/O devices
  - 1st instance where the OS must allocate and schedule resources
    - CPU scheduling
    - Memory management
    - Protection

[lec1] Brief History of Cmputer Systems (2)

- Timesharing systems support interactive use
  - Logical extension of multiprogramming
  - optimize response time by frequent time-slicing multiple jobs
  - each user feels he/she has the entire machine
  - permits interactive work
  - Most systems today are timesharing (focus of this class)

[lec1] Is there a perfect OS?
(resource manager, abstract machine)

Fairness
Efficiency

Portability
Interfaces

Security
Robustness

- Conflicting goals
  - Fairness vs efficiency
  - Efficiency vs portablity
  - …
- Furthermore, …

Challenges in Policy

- Flexibility - variability in job types
  - Long vs. short
  - Interactive vs. non-interactive
  - I/O-bound vs. compute-bound
- Issues
  - Short jobs shouldn't suffer
  - (Interactive) Users shouldn't be annoyed

Challenges in Policy (cont)

- Fairness
  - All users should get access to CPU
  - Amount of CPU should be roughly even?
- Issue
  - Short-term vs. long-term fairness

Goals and Assumptions

- Goals (Performance metrics)
  - Minimize turnaround time: avg time to complete a job
  - Maximize throughput: operations (jobs) per second
    - Minimize overhead of context switches: large quanta
    - Efficient utilization (CPU, memory, disk etc)
  - Short response time: type on a keyboard
    - Small quanta
  - Fairness (fair, no stavaton, no deadlock)
- Goals often conflict
    - Response time vs. throughput
    - fairness vs. avg turnaround time?
- Assumptions
  - One process/program per user
  - Programs are independent

Scheduling policies

- Is there an optimal scheduling policy?
- Even if we narrow down to one goal?
- But we don't know about future
  - Offline vs. online

Queuing Theory:

the mathematical study of waiting lines, or *queues*.

- An entire discipline to itself
- Mathematically oriented
- Some neat results
- Assumptions may be too restrictive to be able to model real-world situations exactly
  - E.g. assume infinite number of customers, infinite queue capacity, or no bounds on inter-arrival or service times
- Systems have grown more complex these days
- (Workload-driven) Simulation used instead now

CPU Scheduling policies

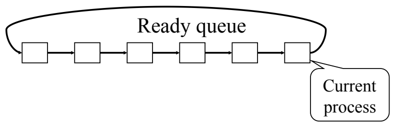
- FIFO
- Round Robin
- SJCF
- SRTCF

(break)

(Non-Preemptive scheduling) FIFO (FCFS) Policy

- What does it mean?
  - Run to completion (old days)
  - Run until blocked or yield
- Advantages
  - Simple
- Disadvantage?

Round Robin



- Each runs a time slice or ***quantum***
- How do you choose time slice?
  - Overhead vs. response time
  - Overhead is typically about 1% or less
  - Quantum typically between 10 ~ 100 millisec

Is Fairness Always Good?

- Assume 10 jobs, each takes 100 seconds
- Assume no other overhead
- Total CPU time? 1000 seconds, always

- Implications?
  - Last job always finishes at 1000 seconds
  - So what’s the point of scheduling?

Adding I/O Into the Mix

- Resource utilization example
  - A and B each uses 100% CPU
  - C loops forever (1ms CPU and 10ms disk)
  - Time slice 100ms: nearly 5% of disk utilization with Round Robin
  - Time slice 1ms: nearly 90% of disk utilization with Round Robin and nearly 100% of CPU utilization
- What do we learn from this example?
  - *Small time slice can improve utilization / fairness to I/O jobs*

Adding I/O Into the Mix

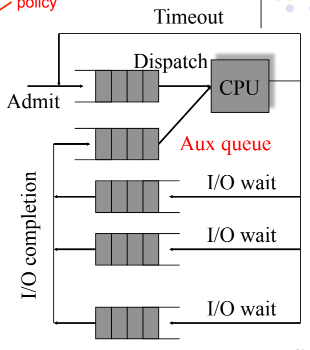
- Can we improve fairness for I/O bound processes without using tiny time slice?

Virtual Round Robin

policy

- To improve fairness for I/O bound processes
- Aux queue is FIFO
- I/O bound processes go to aux queue (instead of ready queue) to get scheduled
- Aux queue has preference over ready queue

mechanism



STCF vs. SRTCF

- Shortest time to completion first (shortest job first)
  - Non-preemptive
- Shortest *remaining* time to completion first
  - Preemptive
- When (what job arrival secenario) are they the same?
- Advantage
  - Minimal average turnaround time
- Disadvantage
  - Can cause starvation; difficult to know the future

Deep thinking

- Can you do better than Shortest job first in terms of average turnaround time?
- Prove it!

Read Chapter 5