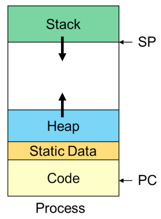
Process Management & Scheduling

ECE 650
Systems Programming & Engineering
Duke University, Spring 2016

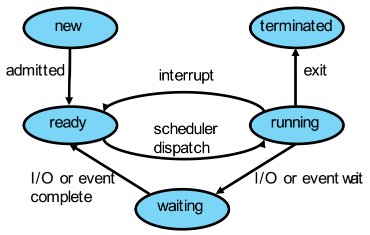
Process



- Process is running instance of a program
  - E.g. program = emacs
  - Can run multiple instances
- Process has an ID
- OS supports processes
  - Resource management
  - Scheduling

Process State

- OS tracks a state for each process



Process Control Block

- How does the OS track & manage processes?
- Process Control Block (PCB)
- Data structure kept by the OS for every process
  - Process state
  - Program Counter
  - CPU registers
  - Scheduling information (e.g. priority, pointers to sched. queues)
  - Memory information (pointers to page tables, etc.)
  - Accounting information (CPU time, process ID, etc.)
  - I/O information (lists of open files, I/O devices, etc.)
- Multi-threaded process?
  - PCB is expanded to store info for each thread

Process Scheduling

- Every HW thread in the system can execute a process
  - It is actually kernel threads that are being scheduled
  - Remember at least 1 thread per process
- Likely more processes active than HW threads
- OS schedules processes on HW threads
  - Process executes for some amount of time
    - Until it needs to block (e.g. for I/O operations)
    - Until its time slice (or quantum) (e.g. 100ms) has elapsed
      - For pre-emptive OS schedulers
  - Gives appearance that more processes than HW threads can be active at one time

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OS Scheduling Queues

- OS uses queue structures for scheduling
  - Linked lists of PCBs
- Created processes are placed on job queue
- Processes ready to execute are placed in "ready queue"
- Processes blocking are placed in "event queues", e.g.
  - Waiting for disk due to a page fault
  - Waiting for input I/O from the keyboard
- Example…

Scheduling Flow

- Process on ready queue is selected to execute
- Process executes until an event happens
  - Waits for I/O request
  - Spawns child process and waits for it to complete
  - Interrupt requires OS service
  - Pre-emption by OS after time slice expires

Context Switch

- OS uses context switch to change the running process
  - Remove running process from the CPU
  - Setup a new process on the CPU to start running
- OS saves all process state from the CPU to PCB
  - Registers, PC, stack pointer
- Load state from PCB of new process to run onto CPU
- Return from interrupt: leave privileged mode, restore PC
- Context switch time is performance overhead
  - Depends on # of registers, HW support in the processor
  - E.g. register windows in SPARC architecture

CPU Scheduling Motivation

- Two sources:
  - Fine-grained sharing of CPU provides illusion of many tasks executing at the same time
  - Processes alternate between CPU processing and I/O activity
    - Many short CPU bursts
    - Few long CPU bursts
- Allow maximum utilization of the CPU

Scheduling Criteria

- Many algorithms for scheduling processes on the CPU
- How to evaluate them?
  - CPU utilization: keep the CPU busy as often as possible
  - Throughput: number of processes completed per unit time
  - Turnaround time: how long to execute a single process
  - Waiting time: amount of time spent in the ready queue
  - Response time: time until start of first response
    - Relevant for interactive jobs
- Typically evaluate based on an average of these metrics
- Some may be more important for certain system uses

First Come, First Serve (FCFS)

- First ready process to arrive gets the CPU
- Implemented with a FIFO of PCBs
- Easy to design and implement
- Possibly poor behavior for certain metrics
  - Waiting time
  - Turnaround time
  - Response time
- Variability causes poor behavior
  - Variability in CPU burst times and CPU vs. I/O mix
- Non-preemptive

Shortest Job First (SJF)

- Pick the shortest job from the ready queue for the CPU
  - Really the shortest next period of CPU activity
- Provably optimal for reducing average waiting time
  - Moving shorter process before a longer one
    - Reduces wait time for shorter process by a large amount
    - Increases wait time for the longer process by a small amount
- Sometimes implemented directly (batch job schedulers)
  - User-requested run-time limit used as the job execution time
- Not feasible directly for OS CPU scheduling
  - Don't know length of next CPU burst
  - But it is possible to try and estimate it

Estimating Next Compute Burst Length

- OS can track an exponential average of previous bursts
  - $T_{n+1} = \alpha * t_n + (1-\alpha)T_n$
  - T_{n+1} = next CPU interval
  - t_n = most recent CPU interval
  - α = weight of most recent recent vs. prior CPU intervals
- CPU burst intervals further in the past have less weight

SJF

- Can be preemptive or non-preemptive
  - Non-preemptive: job remains on CPU until it finishes CPU burst
  - Preemptive: a new process entering ready queue causes scheduler to run again and possibly make a context switch
- Example (times in ms)
  - P0: Arrival Time = 0, Burst Time = 8
  - P1: Arrival Time = 1, Burst Time = 4
  - P2: Arrival Time = 2, Burst Time = 9
  - P3: Arrival Time = 3, Burst Time = 5
  - Wait time average = 6.5 ms for preemptive
  - Wait time average = 7.75 ms for non-preemptive

Priority Scheduling

- A generalization of the SJF algorithm
- Every process has an assigned priority
- Allocate the CPU to the process with the highest priority
  - e.g. based on user assignment (priority + 'nice' value in linux)
  - Or based on process characteristics
- Can also be preemptive or non-preemptive
- Starvation is a problem (for low priority processes)
  - Can be solved with an aging technique
  - Increase the priority of ready processes over time

Round-Robin Scheduling

- A preemptive scheduling approach
- A process executes until:
  - It blocks or ends
  - Its time quantum expires
- OS keeps FIFO of PCBs and cycles through them
  - Newly ready processes are added to the tail
- Sometimes results in longer wait times
- Performance is heavily tied to the length of quantum
  - Too long and it reverts to FCFS
  - Too short and context switch time will dominate
  - Rule of thumb: 80% of CPU bursts should be less than time quantum

Multi-Level Queue Scheduling

- Instead of a single Ready Queue
  - Multiple queues corresponding to different types of processes
    - System, Interactive, Batch, Background
  - Processes assigned to one queue based on their properties
    - E.g. response time requirements
  - Each queue can use a different scheduling policy
    - Round robin for the interactive queue, FCFS for background, etc.
  - Either give each queue an absolute priority or time slice across

Multi-Level Feedback Queue Schedule

- Instead of static allocation of processes to queues…
- Dynamically move processes between them
  - Move processes with heavy CPU bursts to lower priority queues
  - Move I/O & interactive processes to higher priority queues
- Possibly use larger time slices for lower priority queues
- Helps prevent starvation