Advanced Operating Systems (CS 202)

Scheduling (1)

UNIVERSITY OF CALIFORNIA, RIVERSIDE

Today: CPU Scheduling

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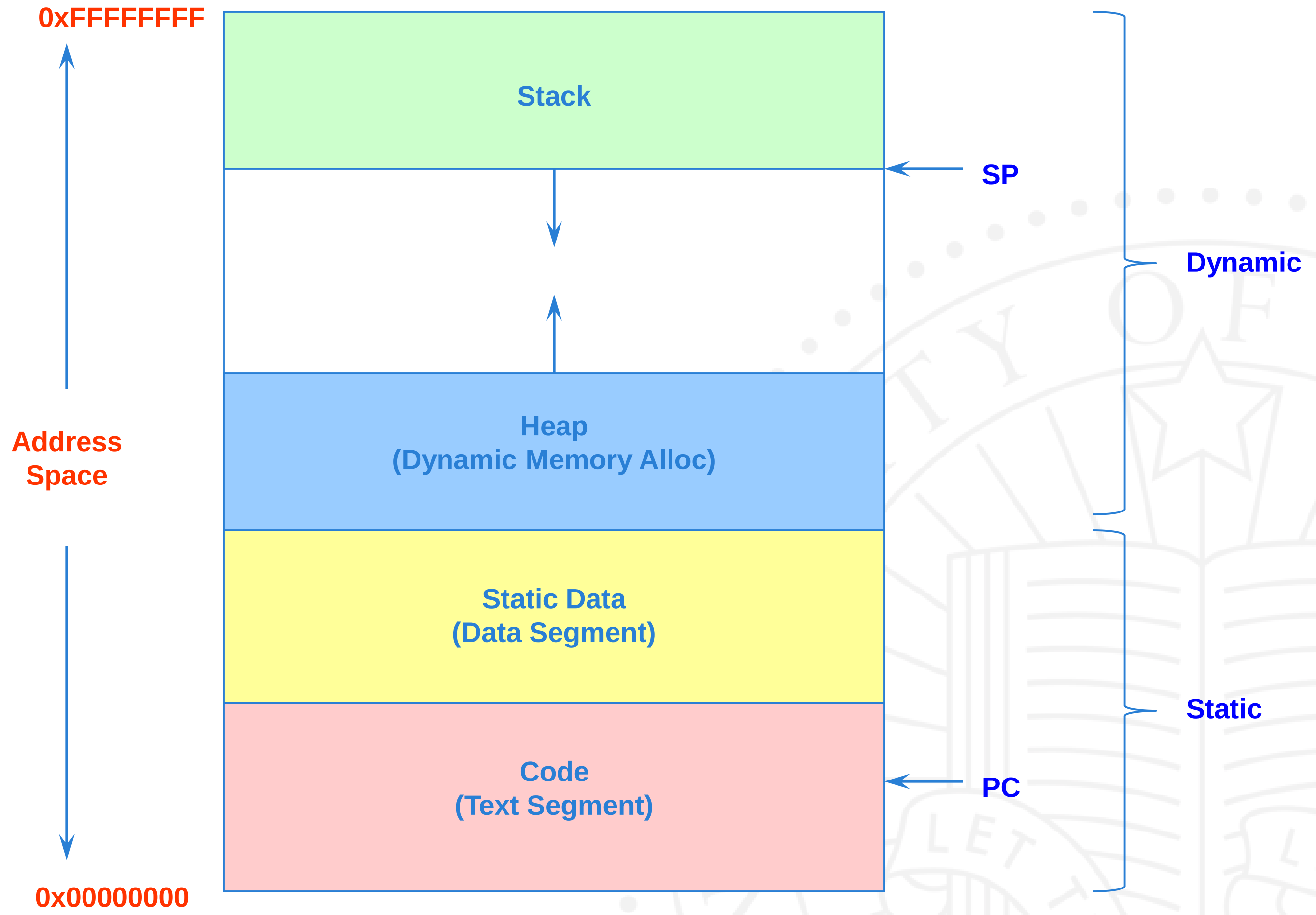
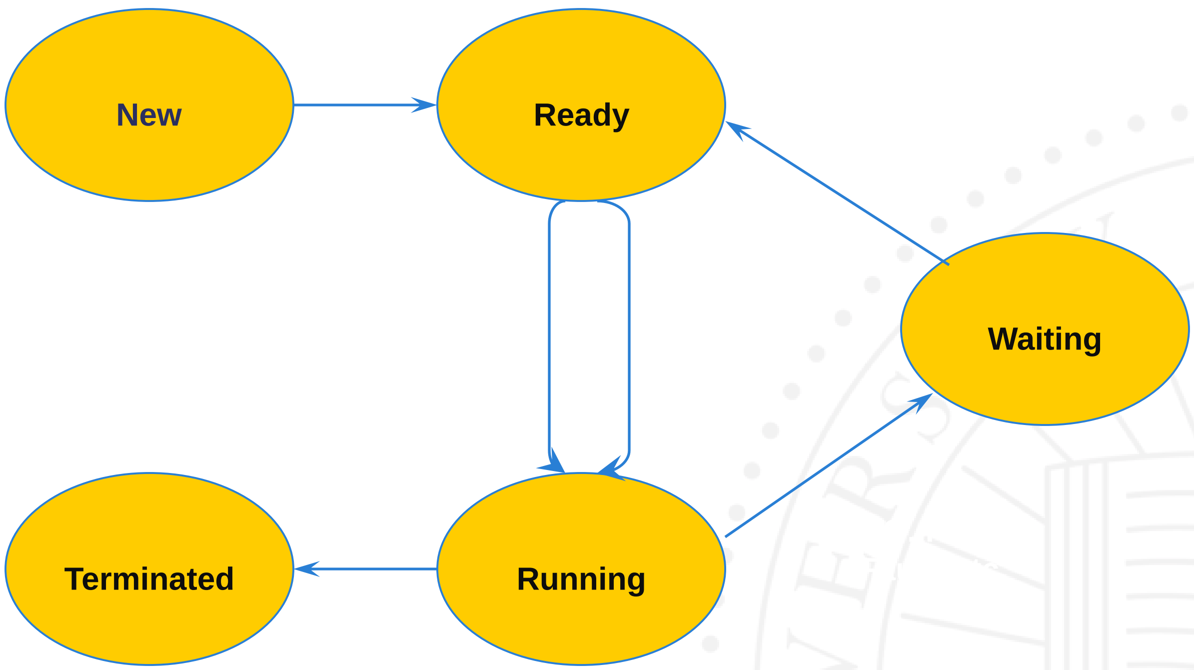
The Process

- The process is the OS abstraction for execution
  - It is the unit of execution
  - It is the unit of scheduling
  - It is the dynamic execution context of a program
  - A process is sometimes called a job or a task
- A process is a program in execution
  - Programs are static entities with the potential for execution
  - Process is the animated/active program
    - Starts from the program, but also includes dynamic state

Process Address Space



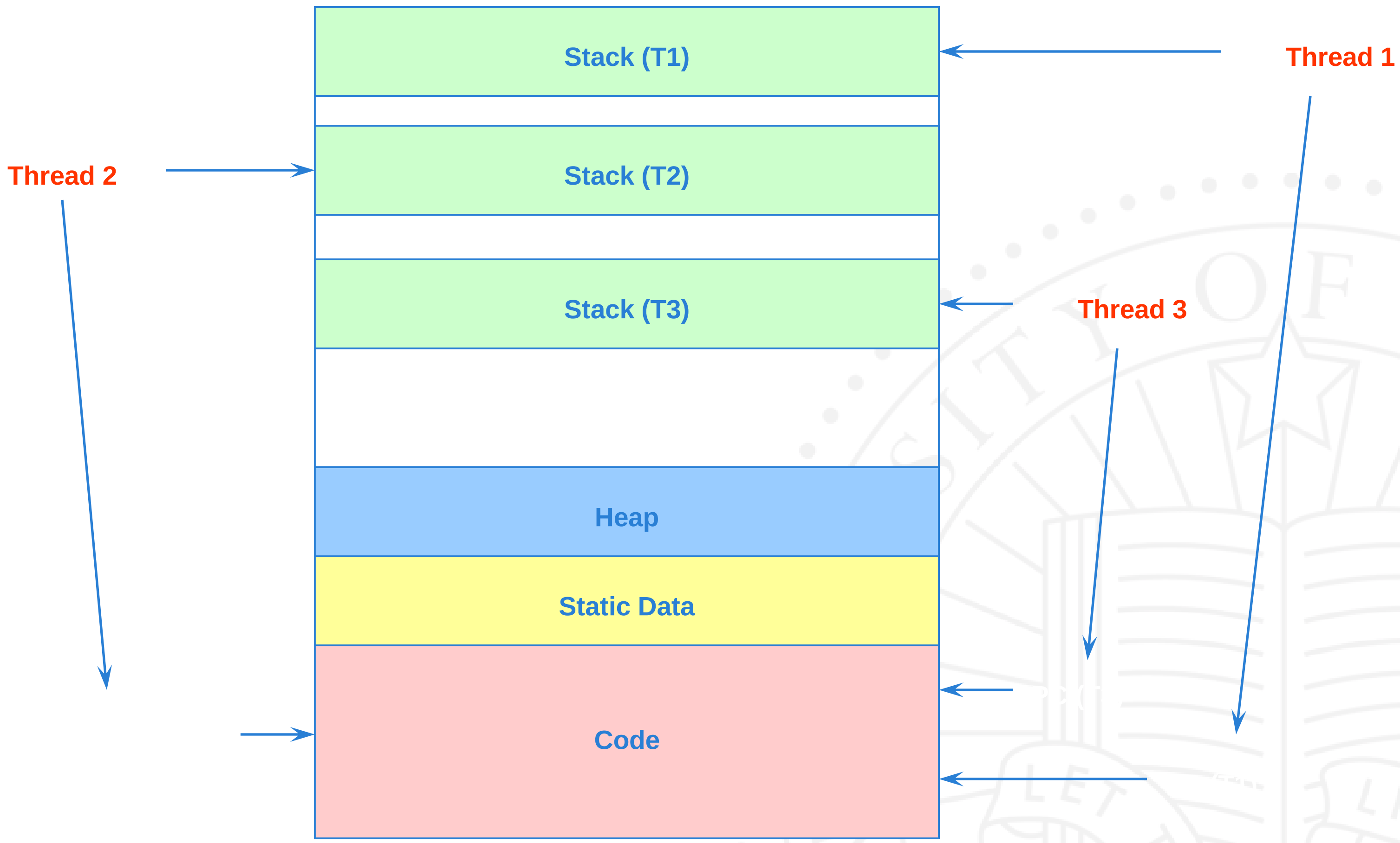
Process State Graph



Threads

- Separate dual roles of a process
  - Resource allocation unit and execution unit
  - A thread defines a sequential execution stream within a process (PC, SP, registers)
  - A process defines the address space, and resources (everything but threads of execution)
- A thread is bound to a single process
  - Processes, however, can have multiple threads
- Threads become the unit of scheduling
  - Processes are now the containers in which threads execute
  - Processes become static, threads are the dynamic entities

Threads in a Process



Thread Design Space

Today: CPU Scheduling

- Scheduler runs when we context switching among processes/threads on the ready queue
  - What should it do? Does it matter?
- Making the decision on what thread to run is called scheduling
  - What are the goals of scheduling?
  - What are common scheduling algorithms?
  - Lottery scheduling
- Scheduling activations
  - User level vs. Kernel level scheduling of threads

Scheduling

- Right from the start of multiprogramming, scheduling was identified as a big issue
  - CCTS and Multics developed much of the classical algorithms

- Scheduling is a form of resource allocation
  - CPU is the resource
  - Resource allocation needed for other resources too; sometimes similar algorithms apply

- Requires mechanisms and policy
  - Mechanisms: Context switching, Timers, process queues, process state information, …
  - Scheduling looks at the policies: i.e., when to switch and which process/thread to run next

Preemptive vs. Non-preemptive scheduling

- In *preemptive* systems where we can interrupt a running job (involuntary context switch)
  - We're interested in such schedulers…
- In *non-preemptive* systems, the scheduler waits for a running job to give up CPU (voluntary context switch)
  - Was interesting in the days of batch multiprogramming
  - Some systems continue to use cooperative scheduling
- Example algorithms:
  - RR, FCFS, Shortest Job First (how to determine shortest), Priority Scheduling

Scheduling Goals

- What are some reasonable goals for a scheduler?
- Scheduling algorithms can have many different goals:
  - CPU utilization
  - Job throughput (# jobs/unit time)
  - Response time (Avg(T_{ready}): avg time spent on ready queue)
  - Fairness (or weighted fairness)
  - Other?

- Non-interactive applications:
  - Strive for job throughput, turnaround time (supercomputers)
- Interactive systems
  - Strive to minimize response time for interactive jobs
- Mix?

Goals II: Avoid Resource allocation pathologies

- Starvation no progress due to no access to resources
  - E.g., a high priority process always prevents a low priority process from running on the CPU
  - One thread always beats another when acquiring a lock
- Priority inversion
  - A low priority process running before a high priority one
  - Could be a real problem, especially in real time systems
    - Mars pathfinder: http://research.microsoft.com/en-us/um/people/mbj/Mars_Pathfinder/Authoritative_Account.html
- Other
  - Deadlock, livelock, convoying …

Non-preemptive approaches

- Introduced just to have a baseline
- FIFO: schedule the processes in order of arrival
  - Comments?
- Shortest Job first
  - Comments?

Preemptive scheduling: Round Robin

- Each task gets resource for a fixed period of time (time quantum)
  - If task doesn’t complete, it goes back in line
- Need to pick a time quantum
  - What if time quantum is too long?
    - Infinite?
  - What if time quantum is too short?
    - One instruction?

Priority Scheduling

- Priority Scheduling
  - Choose next job based on priority
    - Airline check-in for first class passengers
  - Can implement SJF, priority = 1/(expected CPU burst)
  - Also can be either preemptive or non-preemptive
- Problem?
  - Starvation – low priority jobs can wait indefinitely
- Solution
  - “Age” processes
    - Increase priority as a function of waiting time
    - Decrease priority as a function of CPU consumption

Combining Algorithms

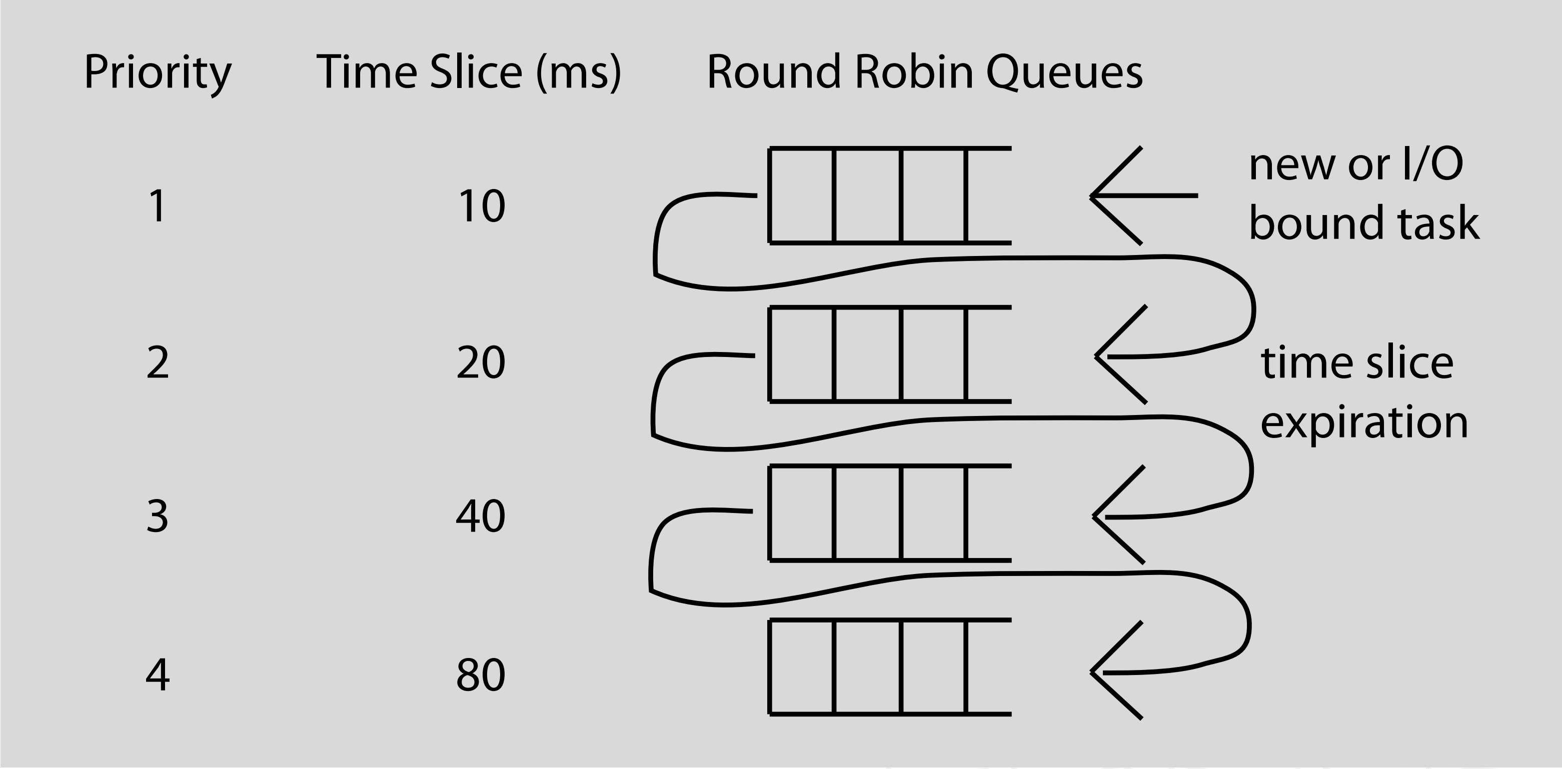
- Scheduling algorithms can be combined
  - Have multiple queues
  - Use a different algorithm for each queue
  - Move processes among queues

- Example: Multiple-level feedback queues (MLFQ)
  - Multiple queues representing different job types
    - Interactive, CPU-bound, batch, system, etc.
  - Queues have priorities, jobs on same queue scheduled RR
  - Jobs can move among queues based upon execution history
    - Feedback: Switch from interactive to CPU-bound behavior

Multi-level Feedback Queue (MFQ)

- Goals:
  - Responsiveness
  - Low overhead
  - Starvation freedom
  - Some tasks are high/low priority
  - Fairness (among equal priority tasks)
- Not perfect at any of them!
  - Used in Unix (and Windows and MacOS)

MFQ


Priority
Time Slice (ms)
Round Robin Queues
1
10
2
20
3
40
4
80
new or I/O bound task
time slice expiration

Unix Scheduler

- The canonical Unix scheduler uses a MLFQ
  - 3-4 classes spanning ~170 priority levels
    - Timesharing: first 60 priorities
    - System: next 40 priorities
    - Real-time: next 60 priorities
    - Interrupt: next 10 (Solaris)
- Priority scheduling across queues, RR within a queue
  - The process with the highest priority always runs
  - Processes with the same priority are scheduled RR
- Processes dynamically change priority
  - Increases over time if process blocks before end of quantum
  - Decreases over time if process uses entire quantum

Linux scheduler

- Went through several iterations
- Currently CFS
  - Fair scheduler, like stride scheduling
  - Supersedes O(1) scheduler: emphasis on constant time scheduling regardless of overhead
  - CFS is O(log(N)) because of red-black tree
  - Is it really fair?
- What to do with multi-core scheduling?