Previous lecture review

- Out of basic scheduling techniques none is a clear winner:
  - FCFS - simple but unfair
  - RR - more overhead than FCFS may not be fair
  - SJF - optimal, but high overhead, starvation possible
  - SRF - optimal, even higher overhead, starvation possible
- combined techniques:
  - priority scheduling
  - multiple feedback scheduling
- all are incorporated in modern OS scheduler design

Lecture 8: Scheduling in modern OS

- non-preemptive kernel to avoid kernel data corruption
- classical Unix (SVR3, 4.3BSD) scheduler design
- real-time requirements
- SVR4 scheduling improvements
- Solaris scheduling improvements
- multiprocessor scheduling

Non-Preemptive Kernel

- To prevent data structures (especially kernel structures) corruption by simultaneous access by different processes/threads we need to ensure *mutual exclusion* of access
- classical approach
  - make kernel non-preemptive - process in kernel mode cannot be suspended when it is in the middle of a shared structure modification
  - disable interrupts when vital structures are modified (see Nachos lecture) - interrupt handler cannot corrupt shared structures modified by kernel
- problems:
  - can be unfair/does not scale
  - cannot be used for real-time scheduling
  - cannot be used for multiprocessor systems

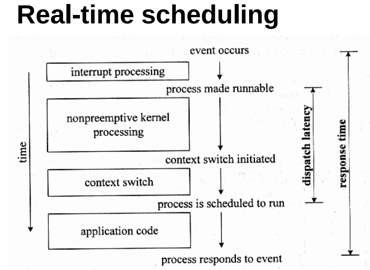
Classical Unix CPU Scheduling (System V release 3(SVR3), 4.3BSD)

- policy:
  - multiple queues (32), each with a priority value - 0-127 (low value = high priority):
    - Kernel processes (or user processes in kernel mode) the lower values (0-49) - kernel processes are not preemptive!
    - User processes have higher value (50-127)
  - Choose the process from the occupied queue with the highest priority, and run that process preemptively, using a timer (time slice typically around 100ms)
    - Round-robin scheduling in each queue
  - move processes between queues
    - Keep track of clock ticks (60/second)
    - add the number of clock ticks to processes (*decaying* processes) in the ready queue
    - Also change priority based on whether or not process has used more than it's "fair share" of CPU time (compared to others)
  - users can decrease (but not increase!) priority

Analysis of classical UNIX CPU scheduling

- advantages:
  - simple (relatively) and effective
  - ok for general purpose, single processor, small sized systems
- disadvantages:
  - re-computing priorities every second is inefficient in large systems
  - no response time guarantee
  - *priority inversion* - a high priority process has to wait for a lower priority process which is in kernel space (non-preemptive kernel) - some kernel code paths take several ms
  - applications do not have adequate control over priority (only superuser can increase)

Real-time scheduling



Reproduced from "Unix Internals" by Uresh Vahalia

- Soft real-time capabilities are needed for quality of service sensitive applications - video, audio, multimedia, virtual reality
- require bounded dispatch latency, and response time

- *dispatch latency* - time from the moment the process becomes runnable to the moment it begins to run
- *response time* = interrupt processing + dispatch latency + real-time process execution

System V release 4 (SVR4) scheduling

- Scheduling classes (in the order of priority):
  - real-time - fixed priority and time slices
  - system - kernel
  - time-sharing (default) - RR scheduling, dynamic priorities, lower priority processes are given larger time slices (to offset overall I/O favoring)
- possibility of adding other classes (dynamic loading of scheduler implementations)
- on-event priority recompilation - priority changes on specific events
  - priority reduced when process uses up time slice
  - priority upped if process blocks
- kernel preemptive in preemption points - points defined where it is safe to preempt the kernel

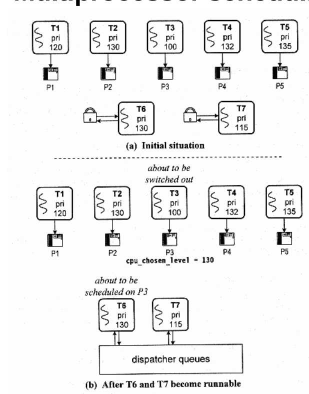
Analysis of SVR4 scheduling

- Advantages
  - flexible, allows real-time, scalable
  - modifiable (allows to add classes)
  - efficient priority computation
  - more balanced scheduling between I/O and CPU bound processes
- Problems
  - switching time sharing -> real-time is not allowed - hand tuning required and not always possible
  - kernel is not completely preemptible
  - no multiprocessor support

Solaris Scheduling

- fully preemptive kernel, shared kernel structures are protected by explicit synchronization mechanisms
- kernel is multithreaded, interrupts are implemented as threads - no need to change interrupt level
- symmetric multiprocessor scheduling
- *priority inheritance* or *priority lending* (solves priority inversion problem) - when a higher priority thread is needs a resources used by a lower priority thread - the higher priority thread *lends* it's priority to the lower priority thread; must be transitive!
- Does not have hard real-time capabilities

Multiprocessor scheduling in Solaris



Reproduced from "Unix Internals" by Uresh Vahalia

- one run queue
- processors communicate through cross-processor interrupts
- example of multiprocessor scheduling (greater number - higher priority):

1. T6, T7 blocked
2. P1 unblocks T6, calls scheduler to find proc. to run it on,
3. scheduler selects T3, and sends it cross-processor interrupt
4. P2 unblocks T7, calls scheduler to find proc to run
5. P2 needs to know that T6 is scheduled on P3!