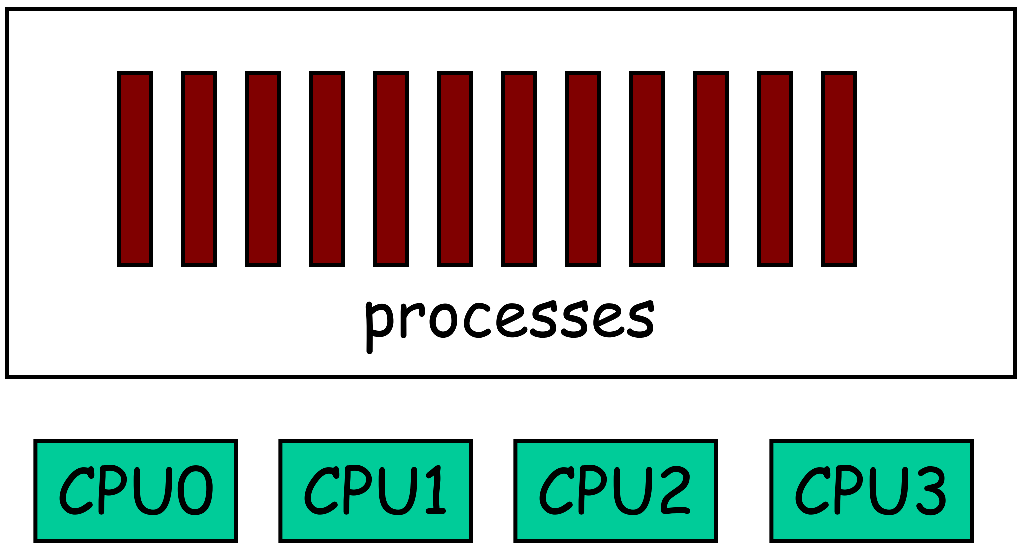
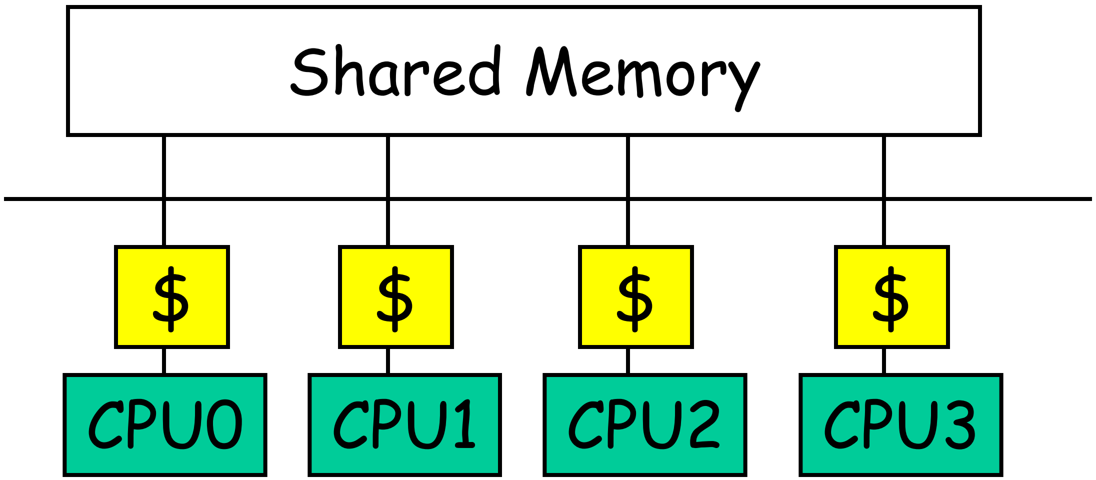
Scheduling II

- Multiprocessor scheduling issues
- Real-time scheduling
- Linux scheduling
- Linux scheduler architecture

How to allocate processes to CPUs?



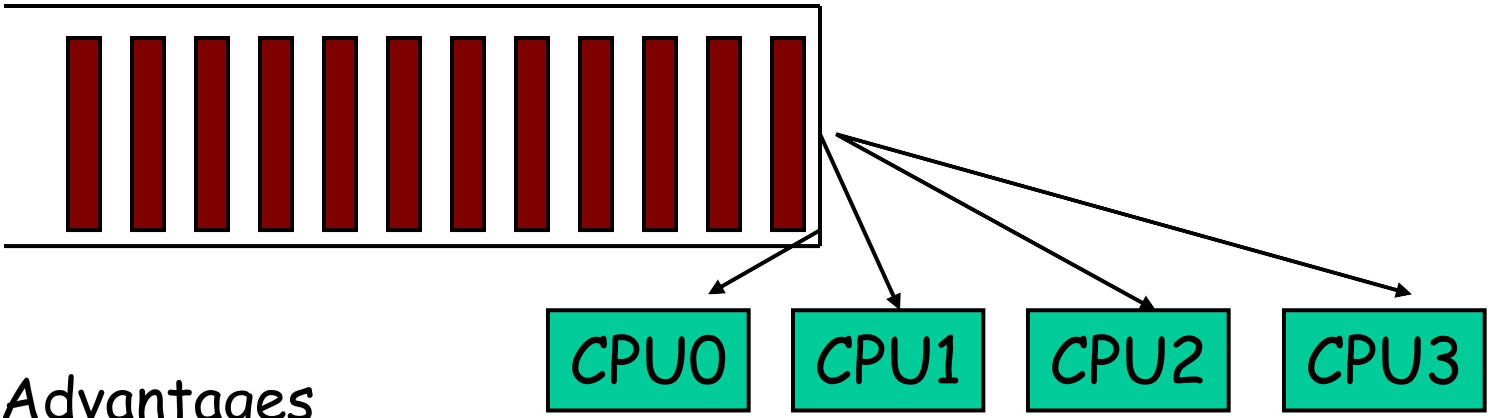
Symmetric multiprocessing (SMP)



- Multiple CPUs
- Same access time to main memory
- Private cache

Global queue of processes

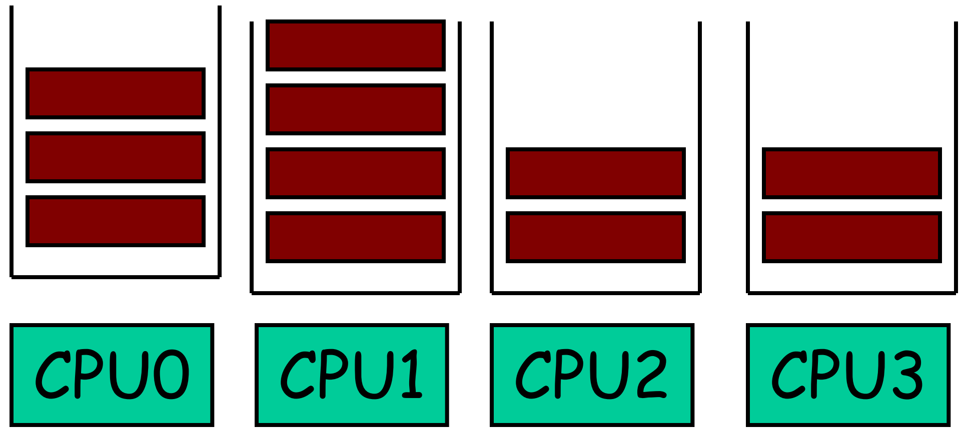
- One ready queue shared across all CPUs



- Advantages
  - Good CPU utilization
  - Fair to all processes
- Disadvantages
  - Not scalable (contention for global queue lock)
  - Poor cache locality
- Linux 2.4 uses global queue

Per-CPU queue of processes

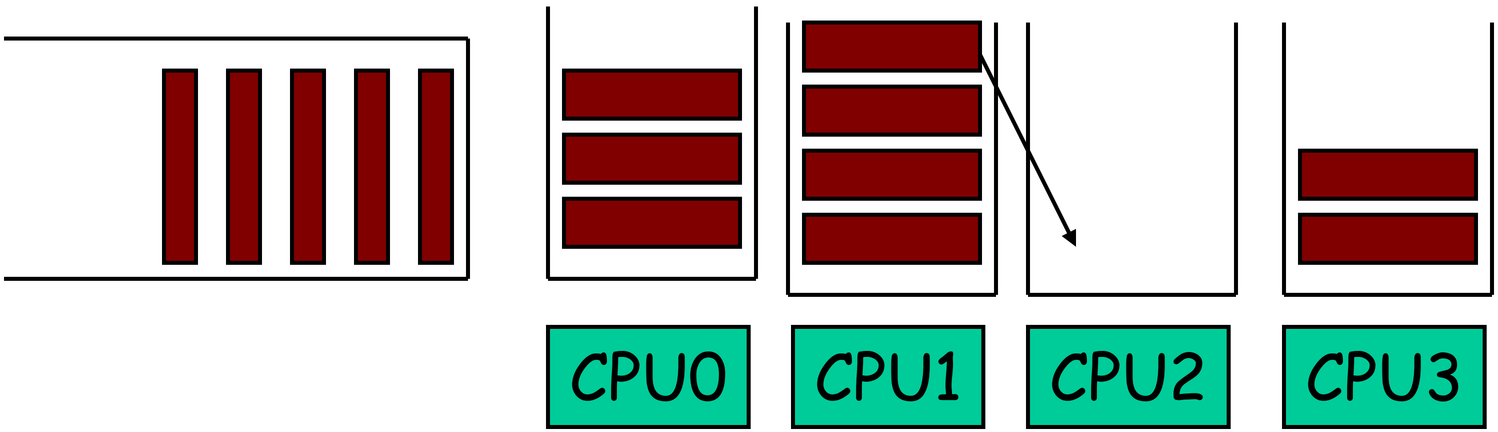
- Static partition of processes to CPUs



- Advantages
  - Easy to implement
  - Scalable (no contention on ready queue)
  - Better cache locality
- Disadvantages
  - Load-imbalance (some CPUs have more processes)
    - Unfair to processes and lower CPU utilization

Modern OSes take hybrid approaches

- Use both global and per-CPU queues
- Migrate processes across per-CPU queues



- Processor Affinity
  - Add process to a CPU's queue if recently run on the CPU
    - Cache state may still present

Real-time scheduling

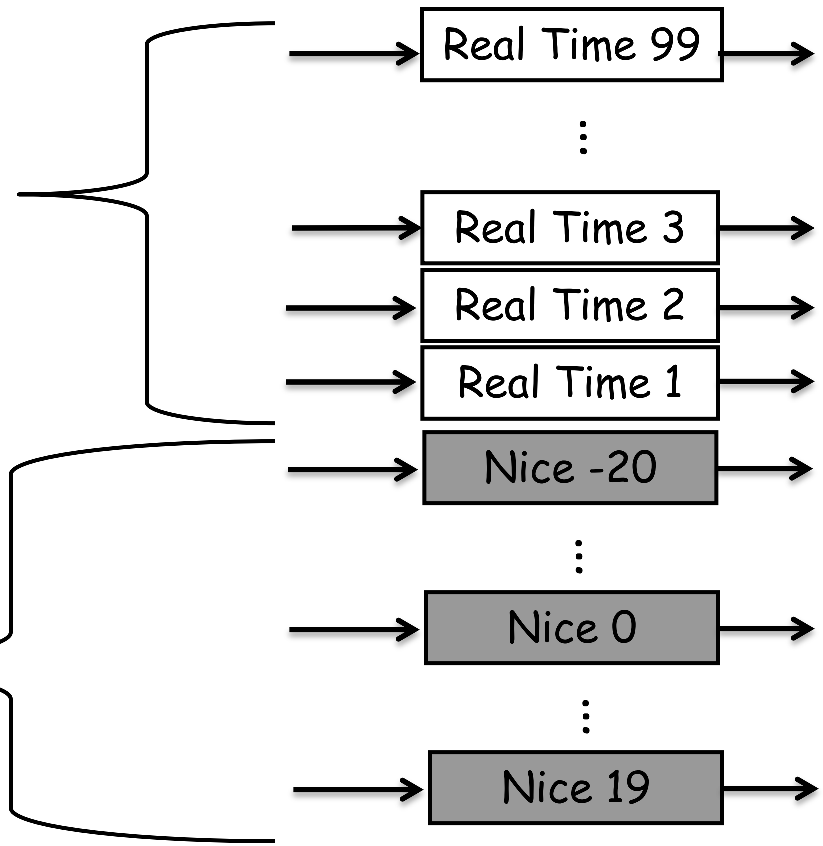
- Real-time processes have timing constraints
  - Expressed as deadlines or rate requirements
  - Ex) gaming, video/music player, autopilot

- Hard real-time systems – required to complete a critical task within a guaranteed amount of time
- Soft real-time computing – requires that critical processes receive priority over others

- Linux supports soft real-time

Linux: multi-level queue with priorities

- Soft real-time scheduling policies
  - SCHED_FIFO (FCFS)
  - SCHED_RR (round robin)
  - Priority over normal tasks
  - 100 static priority levels (1..99)
- Normal scheduling policies
  - SCHED_NORMAL: standard
    - SCHED_OTHER in POSIX
  - SCHED_BATCH: CPU bound
  - SCHED_IDLE: lower priority
  - Static priority is 0
    - 40 dynamic priority
    - "Nice" values
- sched_setscheduler(), nice()
- See "man 7 sched" for detailed overview

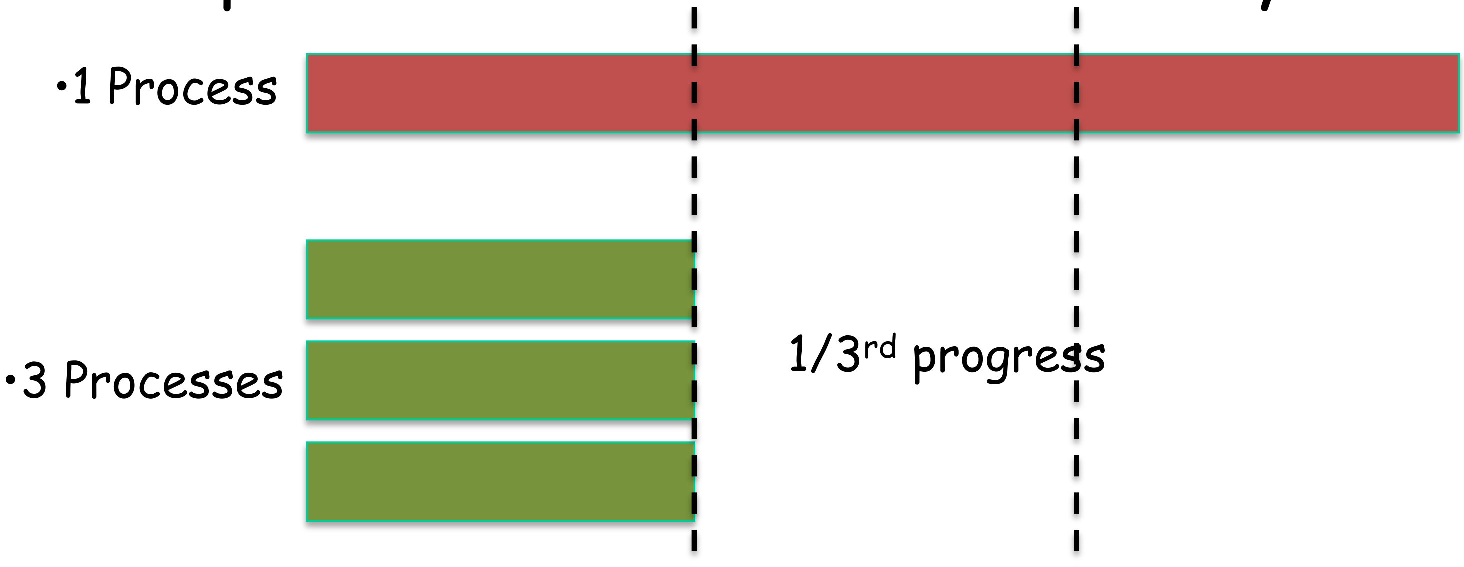


Linux scheduler history

- O(N) scheduler up to 2.4
  - Simple: global run queue
  - Poor performance on multiprocessor and large N
- O(1) scheduler in 2.5 & 2.6
  - Good performance: per-CPU run queue
  - Complex and error prone logic to boost interactivity
  - No fairness guarantee
- Completely Fair Scheduler (CFS) in 2.6 and later
  - Currently default scheduler for SCHED_NORMAL
  - Processes get fair share of CPU
  - Naturally boosts interactivity
- BFS and MuQSS
  - Linux scheduler for hippies
  - Available as kernel patches on the street

Ideal fair scheduling

- Infinitesimally small time slice
- n processes: each runs uniformly at $1/n^{th}$ rate



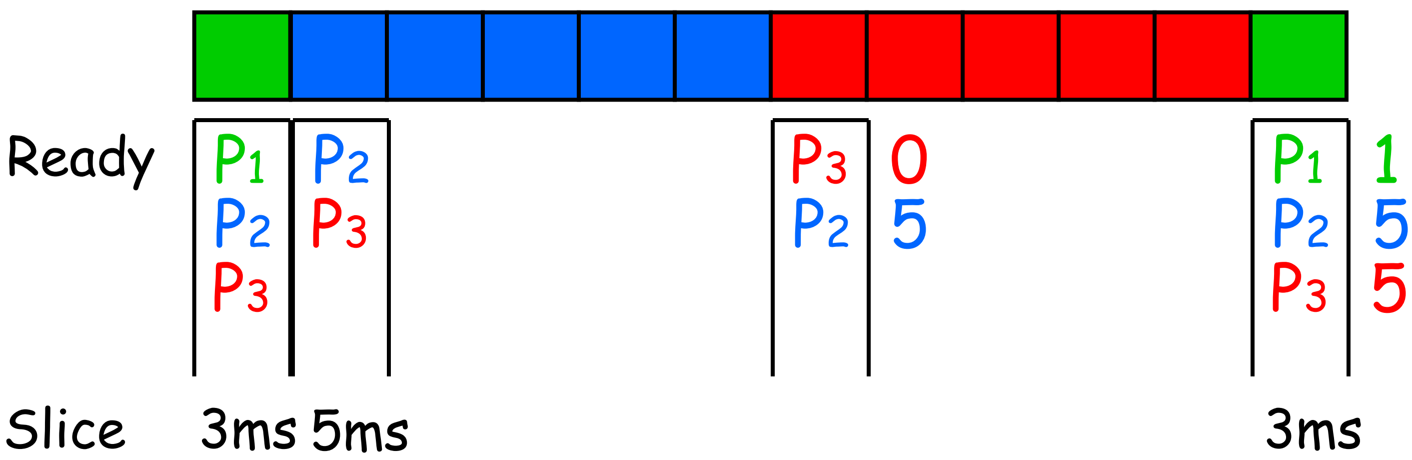
- Various approximations of the ideal
  - Lottery scheduling
  - Stride scheduling
  - Linux CFS

Completely Fair Scheduler (CFS)

- Approximate fair scheduling
  - Run each process once per schedule latency period
    - sysctl_sched_latency
  - Time slice for process Pi: T * Wi/(Sum of all Wi)
    - sched_slice()
- Too many processes?
  - Lower bound on smallest time slice
  - Schedule latency = lower bound * number of procs
- Introduced in Linux 2.6.23

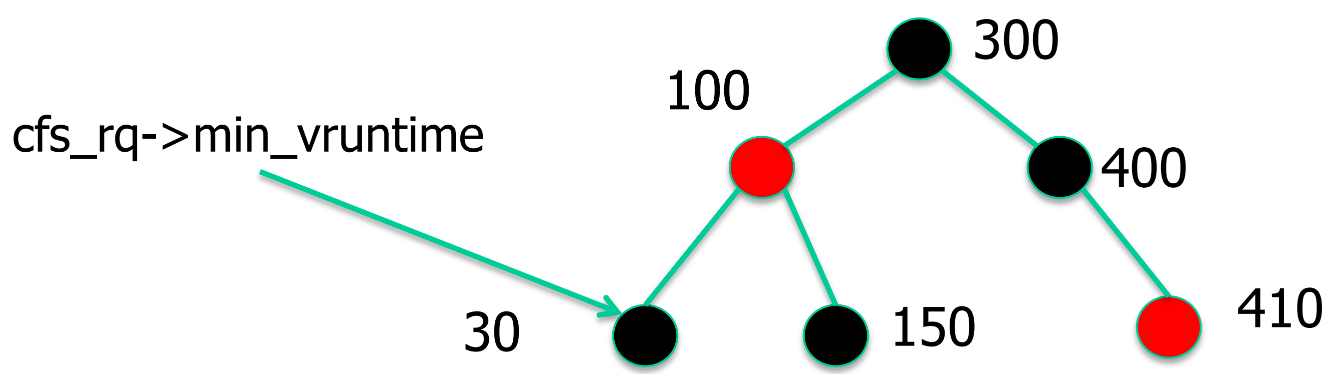
Picking the next process

- Pick proc with weighted minimum runtime so far
  - Virtual runtime: task->vruntime += executed time / Wi
- Example
  - P1: 1 ms burst per 10 ms (schedule latency)
  - P2 and P3 are CPU-bound
  - All processes have the same weight (1)



Finding proc with minimum runtime fast

- Red-black tree
  - Balanced binary search tree
  - Ordered by vruntime as key
  - O(lgN) insertion, deletion, update, O(1): find min



- Tasks move from left of tree to the right
- min_vruntime caches smallest value
- Update vruntime and min_vruntime
  - When task is added or removed
  - On every timer tick, context switch

Converting nice level to weight

- Table of nice level to weight
  - static const int prio_to_weight[40] (kernel/sched/sched.h)
- Nice level changes by 1 ➔ 10% weight
- Pre-computed to avoid
  - Floating point operations
  - Runtime overhead

Fsck all that...

Enter BFS

The scheduler that shall not be named

(now replaced by MuQSS, sadly...)