ECE3140 / CS3420
Embedded Systems

Conventional Scheduling Algorithms

Prof. José F. Martínez

Cornell University

Scheduling Algorithms

- Preemptive or Non-preemptive
- Static or Dynamic
  - Are the scheduling decisions based on parameters that change with time?
  - Fixed-priority vs. dynamic-priority
- Online or Offline
  - Are the decisions made a priori with knowledge of task activations, or are they taken at run time based on the set of active tasks?
- Optimal or Heuristic
  - Can you prove that the algorithm is optimal in terms of a certain criteria or not?

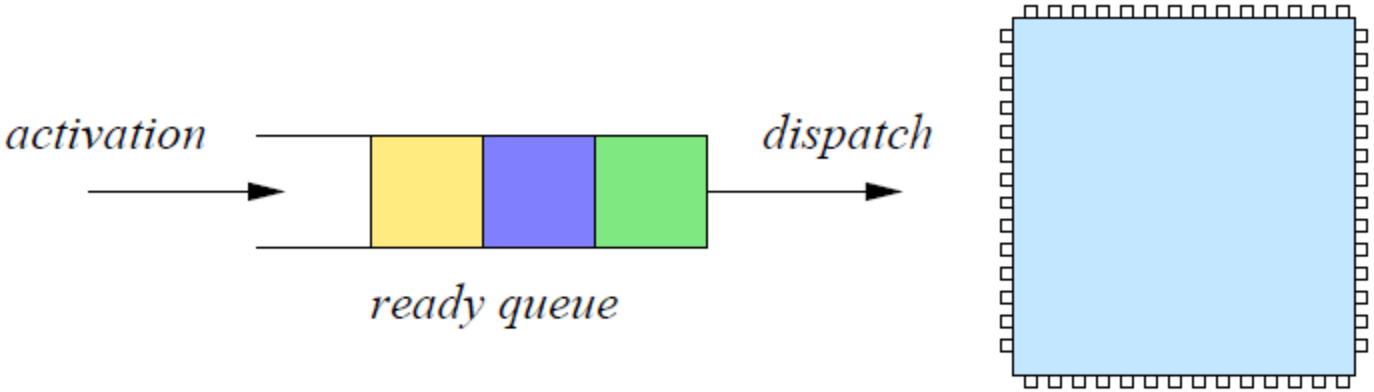
Outline: Conventional Scheduling

Scheduling algorithms for non-real-time systems

- A metric: average response time
- First Come First Served (FCFS)
- Shortest Job First (SJF)
- Priority Scheduling
- Round Robin (RR) Scheduling

Scheduling Algorithm

- Scheduling algorithm: the strategy used to pick a ready task for execution

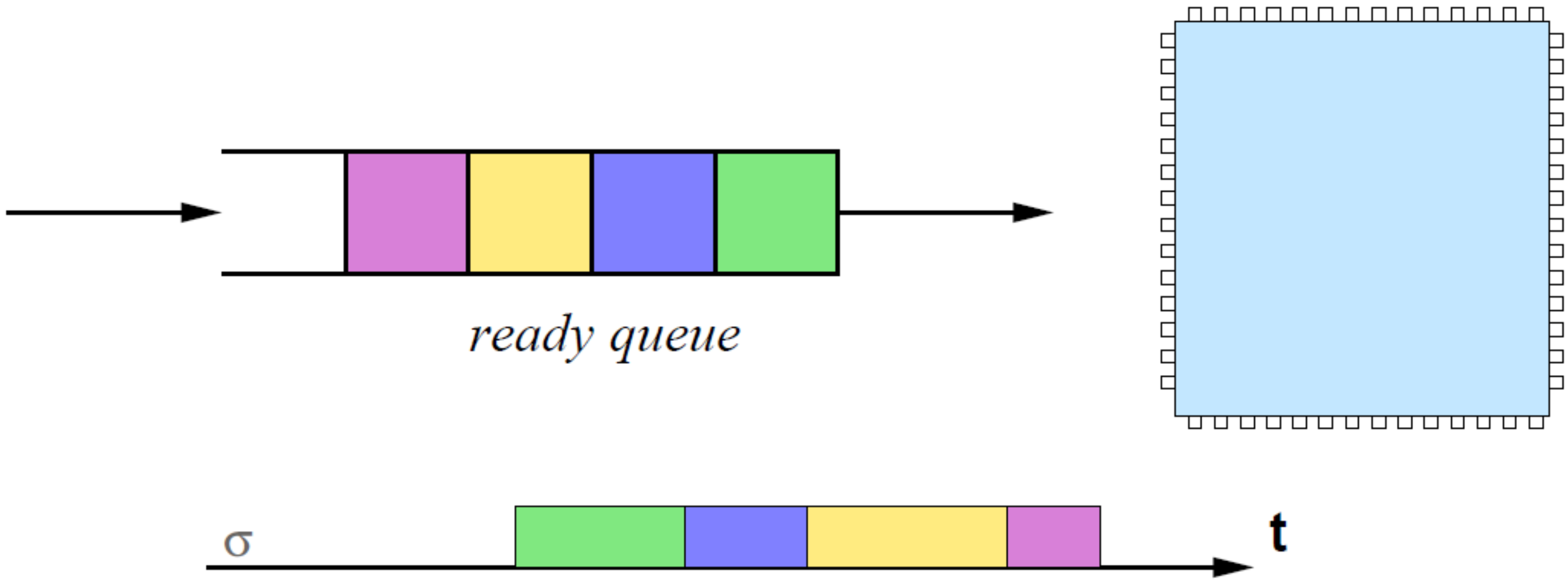


- Let us first consider non-preemptive scheduling
  - *Preemptive*: The running task can be temporarily suspended to execute another task
  - *Non-preemptive*: The running task cannot be suspended until completion or until it is blocked

Metric: Average Response Time

- Goal: minimize the average time that a customer (job) waits in the line (ready queue)
- Response time: $R_i = f_i - r_i$
- Average response time:
  $\frac{1}{n}\sum_{i=1}^{n} R_i = \frac{1}{n}\sum_{i=1}^{n}(f_i - r_i)$

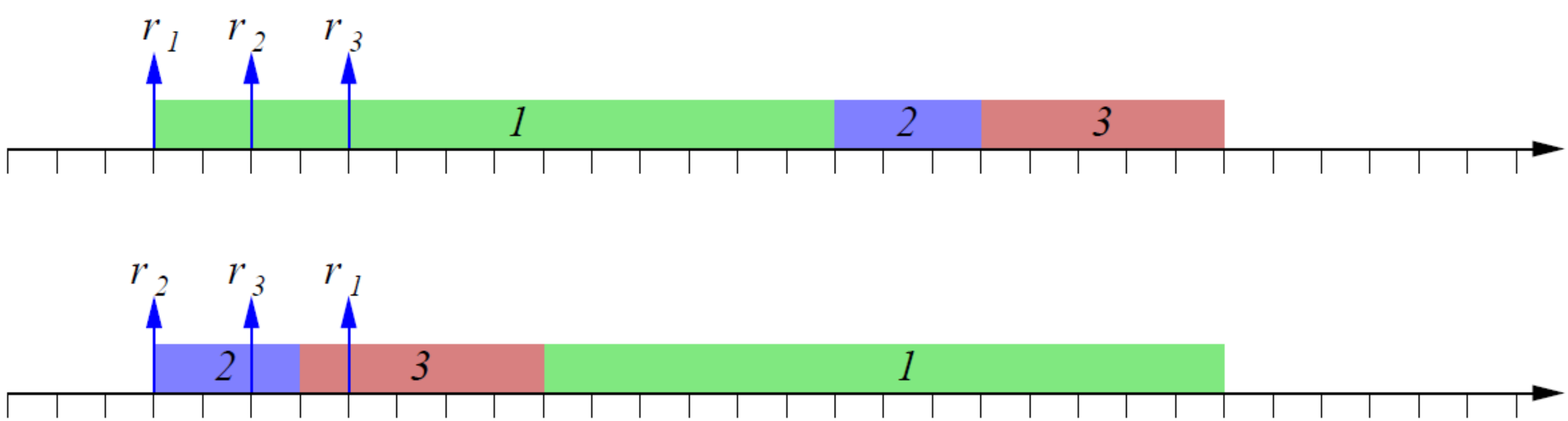
First Come First Served (FCFS)



- One of the most popular classical scheduling policies

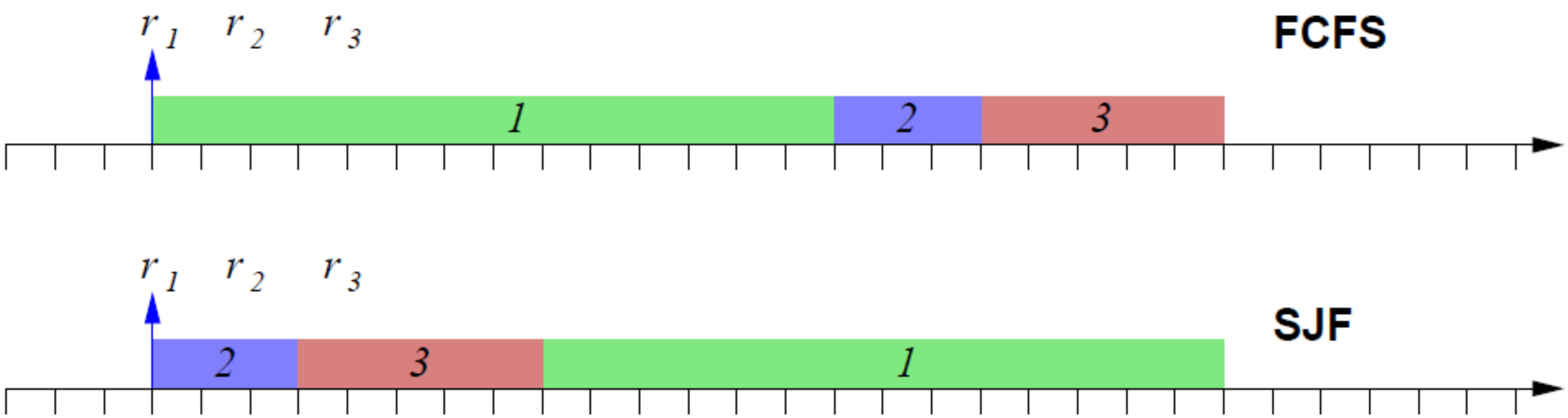
Predictability of FCFS

- FCFS is rather unpredictable: response time depends strongly on task arrival times
  → *not suitable for real-time systems*



Shortest Job First (SJF) Policy

- Pick the task with the shortest computation time



- Optimal
  - SJF minimizes the average response time
- Non-preemptive
  - Preemptive version is often called Shortest Time-to-Completion First (STCF)

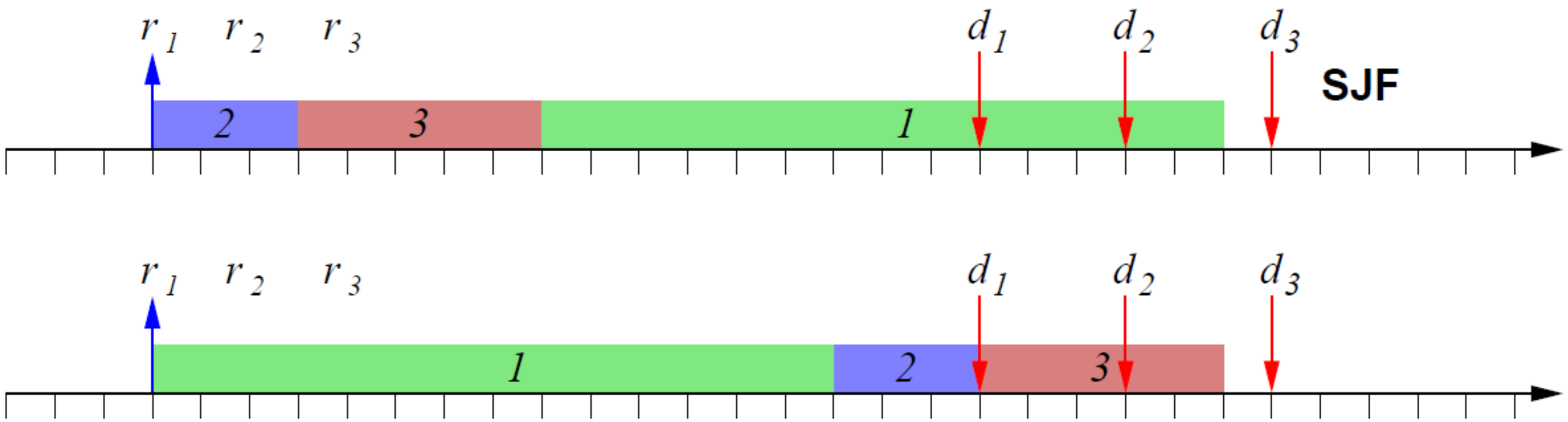
Optimality: Proof Sketch?

Given n tasks, show that $\sigma_{SJF} = \tau_1\tau_2 \ldots \tau_n$ where $C_1 \leq C_2 \leq \cdots \leq C_n$ minimizes the average response time ($\frac{1}{\mathrm{n}}\sum_{i=1}^{n} f_i$). Assume that the arrival time is zero for all tasks ($r_i = 0$).

Consider a schedule $\sigma = \tau_1\tau_2 \ldots \tau_k\tau_{l1}\tau_{l2} \ldots$ where the first k tasks are the same as σ_{SJF} but $\tau_{l1} > \tau_{l2}$

Now consider the schedule $\sigma' = \tau_1\tau_2 \ldots \tau_k\tau_{l2}\tau_{l1} \ldots$ that is identical to σ except for switching τ_{l1} and τ_{l2}. If $\bar{R}(\sigma)$ is the average response time for σ, how do $\bar{R}(\sigma)$ and $\bar{R}(\sigma')$ compare?

What about Real-Time Constraints?



- SJF is NOT optimal for real-time in the sense of feasibility!

Priority Scheduling

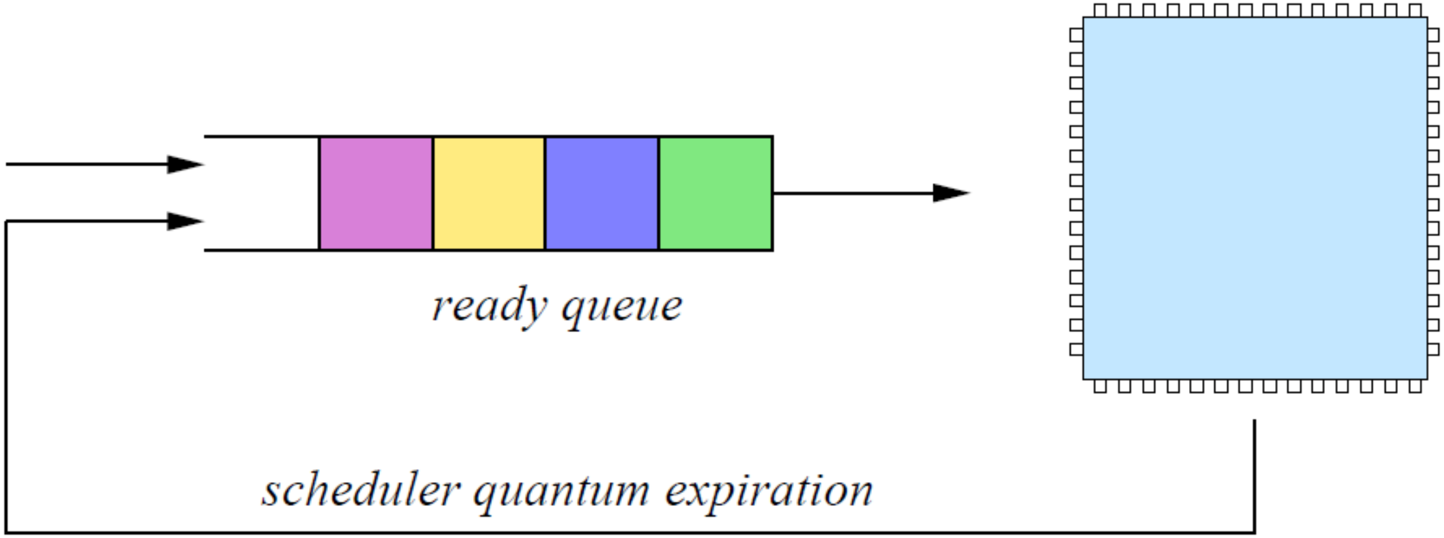
- Each task is assigned a priority
  - Example: $p_i \in [0,255]$ (one byte to store priority)
- Task with the highest priority is selected first
- Tasks with the same priority are scheduled using FCFS

More on Priority Scheduling

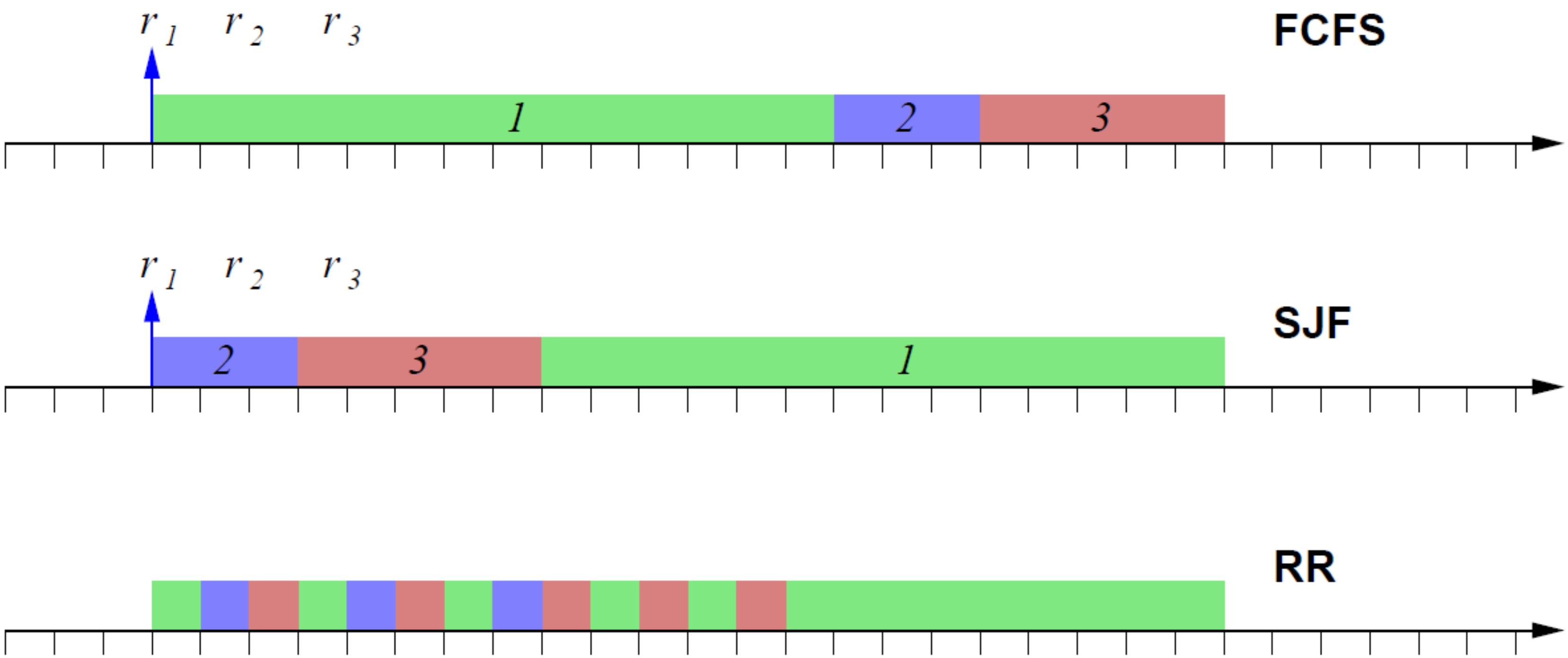
- Starvation
  - Low priority tasks may experience very long delays due to preemption by higher priority tasks
- Common approach to handle starvation
  - Aging: priority increases with waiting time
- Priority scheduling can be used to implement other policies
  - If $p_i \propto 1/C_i$: a preemptive version of shortest job first!
  - If $P_i = 1/r_i$: FCFS (assume $r_i > 0$)

Round Robin (RR) Scheduling

- The ready queue is FCFS
- However . . .
  - Each task cannot execute more than Q time units (the quantum)
  - When Q time units have elapsed, the task is put back into the ready queue



Round Robin Scheduling Example



- What are the advantages of RR over SJF/STCF?

Round Robin Scheduling Properties

- If there are n tasks in the system,
  - Each repeating sequence in the schedule is nQ in length
  - In each repeating sequence, a task gets Q units of time
  - Suppose context switch time δ
- Hence,

$$R_i = f_i - r_i \approx n(Q + \delta)\frac{C_i}{Q} = nC_i\left(1 + \frac{\delta}{Q}\right)$$

- For small Q and negligible δ:
  - Each task runs as if it were executing on a virtual processor that is n times slower than the real one
- If Q is very large, then RR ≡ FCFS