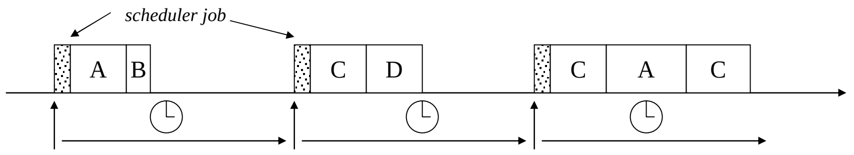
Common Approaches to Real-Time Scheduling

- **Clock-driven** (time-driven) schedulers
  - Scheduling decisions are made at *specific time instants*, which are typically chosen *a priori*.
- **Priority-driven** schedulers
  - Scheduling decisions are made when particular events in the system occur, *e.g.*
    - a job becomes available
    - processor becomes idle
  - **Work-conserving**: processor is busy whenever there is work to be done.

Clock-Driven (Time-Driven) -- Overview

- **Scheduling decision time**: point in time when scheduler decides which job to execute next.
- Scheduling decision time in clock-driven schedulers is defined *a priori*.
- For example: Scheduler periodically wakes up and generates a portion of the schedule.



- Special case: When job parameters are known *a priori*, schedule can be precomputed off-line, and stored as a table (table-driven schedulers).

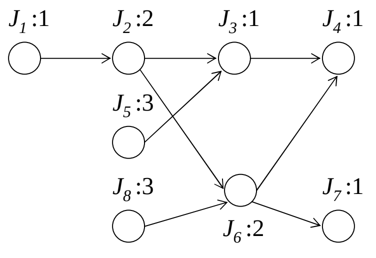
Priority-Driven -- Overview

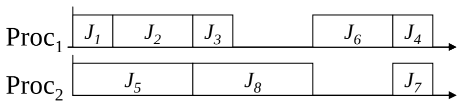
- Basic rule: Never leave processor idle when there is work to be done.
  (such schedulers are also called **work conserving**)
- Based on list-driven, greedy scheduling.
- Examples: FIFO, LIFO, SET, LET, EDF.

- Possible **implementation** of preemptive priority-driven scheduling:
  - Assign priorities to jobs.
  - Scheduling decisions are made when
    - Job becomes ready
    - Processor becomes idle
    - Priorities of jobs change
  - At each scheduling decision time, chose ready task with highest priority.

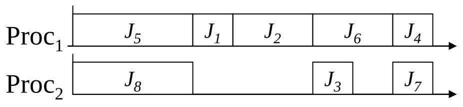
- In non-preemptive case, scheduling decisions are made only when processor becomes idle.

Example: Priority-Driven Non-Preemptive Schedules

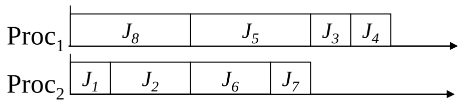




L = (J_1 , J_2 , J_3 , J_4 , J_5 , J_6 , J_7 , J_8)



LET = (J_5 , J_8 , J_2 , J_6 , J_1 , J_3 , J_4 , J_7)



L = (J_8 , J_1 , J_2 , J_3 , J_4 , J_5 , J_6 , J_7)

Effective Timing Constraints

- Timing constraints often inconsistent with precedence constraints.
  Example: $d_1 > d_2$, but $J_1 \rightarrow J_2$
- Effective timing constraints on single processor:
- Effective release time: $r_i^{eff} := \max\left(r_i, \left\{r_j^{eff} \middle| J_j \rightarrow J_i\right\}\right)$
- Effective deadline: $d_i^{eff} := \min\left(d_i, \left\{d_j^{eff} \middle| J_i \rightarrow J_j\right\}\right)$
- Theorem: A set of Jobs ***J*** can be feasibly scheduled on a processor if and only if it can be feasibly scheduled to meet all effective release times and deadlines.

Interlude: The EDF Algorithm

- The EDF (earliest-deadline-first) algorithm:
  At any time, execute that available job with the earliest deadline.
- Theorem: **(Optimality of EDF)** In a system one processor and with preemptions allowed, EDF can produce a feasible schedule of a job set ***J*** with arbitrary release times and deadlines *iff* such a schedule exists.
- Proof: by schedule transformation.

EDF Not Always Optimal

- Case 1: When preemption is not allowed:

$$\begin{array}{lccccccc} & & & r_i & d_i & e_i & \\ J_1 & = & (& 0, & 10, & 3 &) \\ J_2 & = & (& 2, & 14, & 6 &) \\ J_3 & = & (& 4, & 12, & 4 &) \end{array}$$

- Case 1: On more than one processor:

$$\begin{array}{lccccccc} & & & r_i & d_i & e_i & \\ J_1 & = & (& 0, & 4, & 1 &) \\ J_2 & = & (& 0, & 4, & 1 &) \\ J_3 & = & (& 0, & 5, & 5 &) \end{array}$$