Graceful Degradation in Semi-Clairvoyant Scheduling

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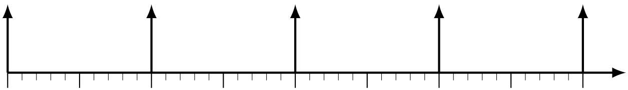
ECRTS 2021

Semi-clairvoyant mixed-criticality scheduling

Non-clairvoyant:
(ordinary MC)



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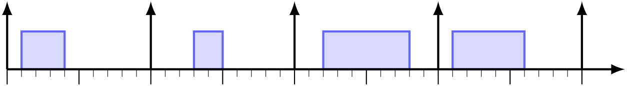

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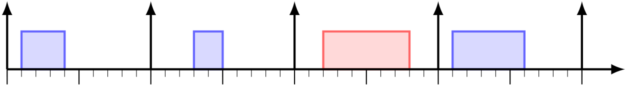

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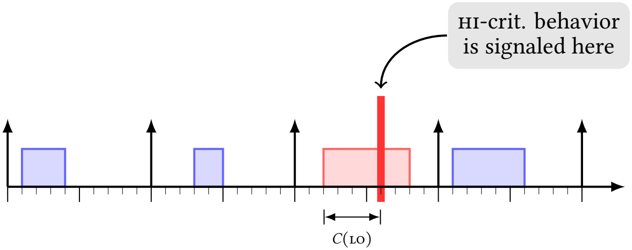

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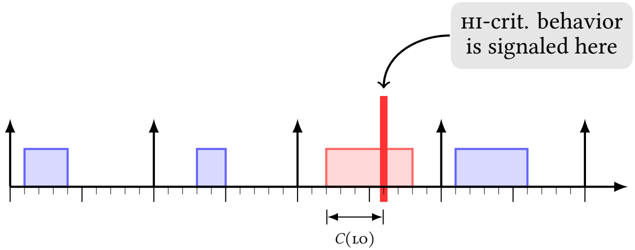
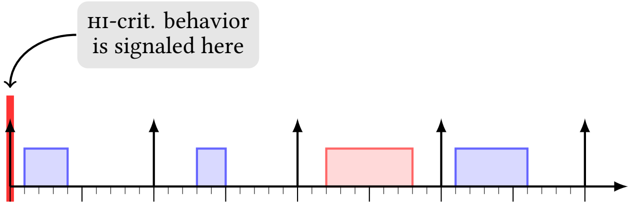


Clairvoyant:



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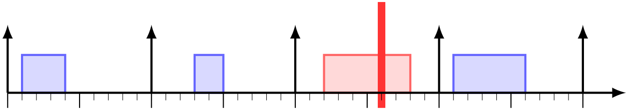

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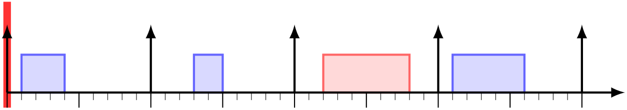

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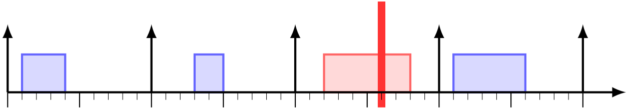

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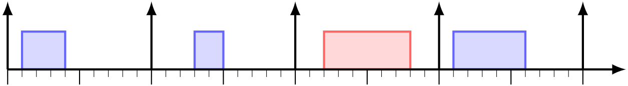
(Agrawal et al., RTSS'19)



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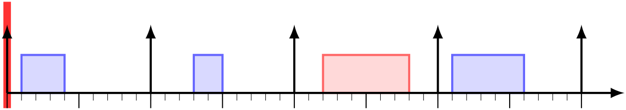

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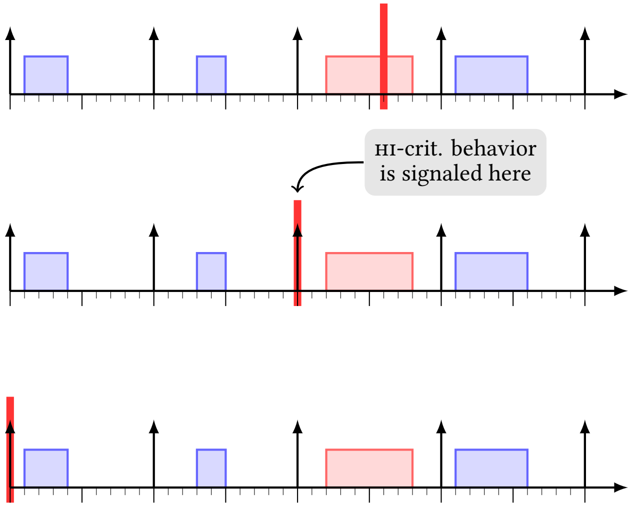

Graceful degradation – what we mean

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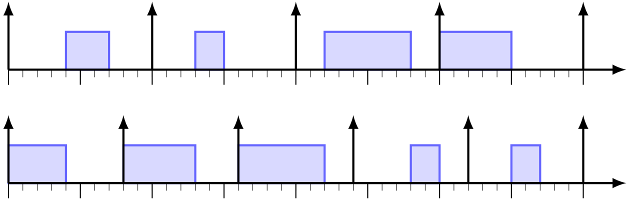

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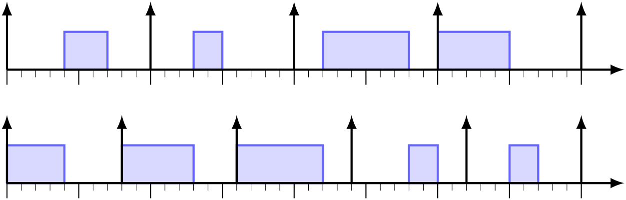

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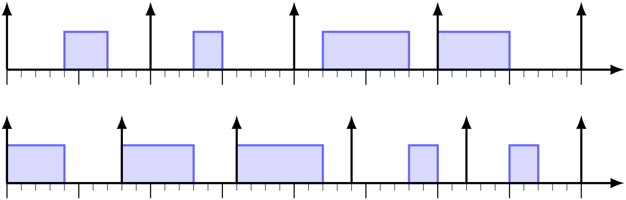

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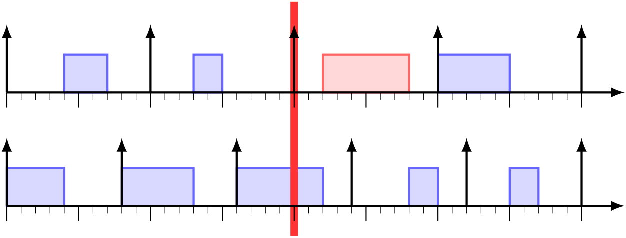

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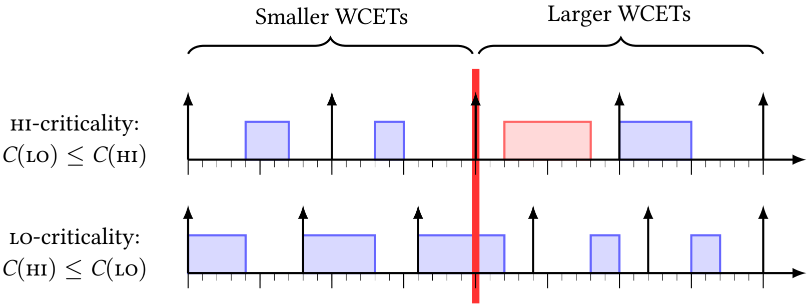

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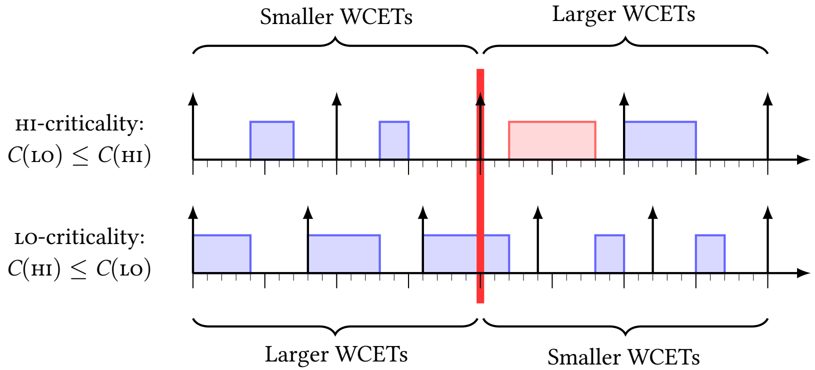

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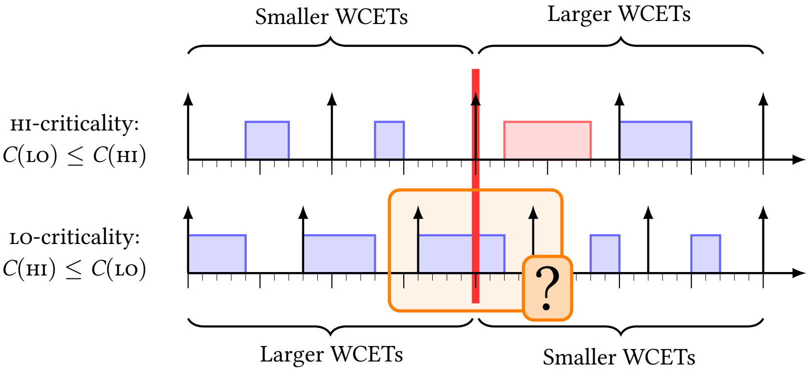

Three different correctness criteria

CC-1

No active LO-crit. job gets to keep their $C(\text{LO})$ budgets.

Three different correctness criteria

CC-1

No active LO-crit. job gets to keep their $C(\text{LO})$ budgets.

CC-1 reduces to the *standard mixed-criticality semantics* in the absence of graceful degradation (i.e., if $C(\text{HI}) = 0$).

Three different correctness criteria

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No active LO-crit. job gets to keep their $C(\text{LO})$ budgets.

CC-2

Active LO-crit. jobs that have *started execution* get to keep their $C(\text{LO})$ budgets.

Three different correctness criteria

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No active LO-crit. job gets to keep their $C(\text{LO})$ budgets.

CC-2

Active LO-crit. jobs that have *started execution* get to keep their $C(\text{LO})$ budgets.

CC-3

All active LO-crit. jobs get to keep their $C(\text{LO})$ budgets.

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CC-2

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CC-3

All active LO-crit. jobs get to keep their $C(\text{LO})$ budgets.

$$\text{CC-3} \implies \text{CC-2} \implies \text{CC-1}$$

All the problems

We consider *optimal scheduling* and *exact analysis* in different settings:

- With one of three correctness criteria:
  1. CC-1
  2. CC-2
  3. CC-3

- With one of two workload models:
  1. Independent jobs
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All the problems

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  1. Independent jobs
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- Semi-clairvoyant scheduling
- Graceful degradation
- A preemptive uniprocessor

Correctness criterion CC-1 — insights

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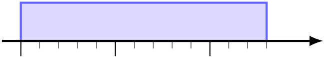

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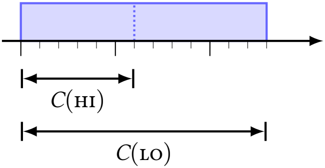

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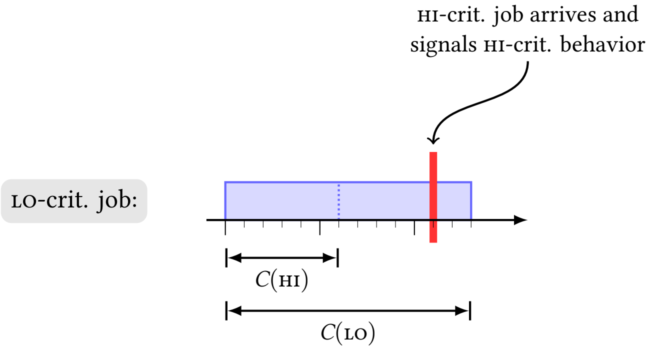

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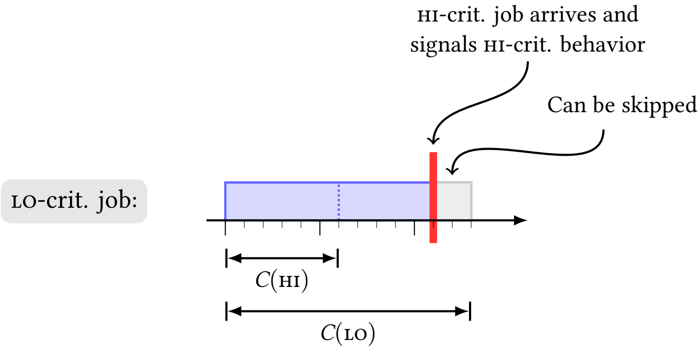

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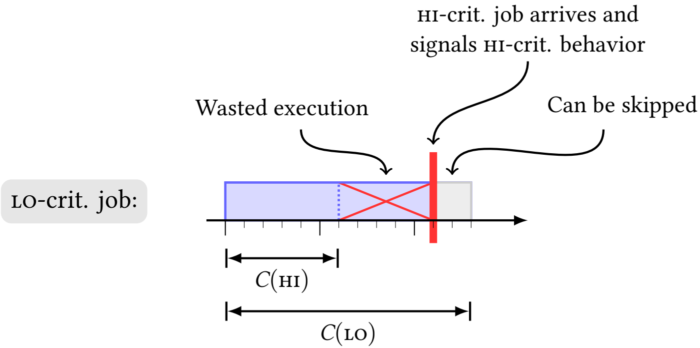

CC-1 — RESULTS

Prior work

CC-1 without graceful degradation (i.e., $C(\textsc{hi}) = 0$ for LO-crit. jobs) is the setting in Agrawal et al., RTSS'19.

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1. A polynomial-time solution for jobs:
   - A Linear Program (LP) for exactly solving the feasibility problem.
   - A table-based optimal scheduler extracted from the LP solution.

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1. A polynomial-time solution for jobs:
   - A Linear Program (LP) for exactly solving the feasibility problem.
   - A table-based optimal scheduler extracted from the LP solution.
2. A polynomial-time solution for implicit-deadline sporadic tasks.
   - An exact utilization-based feasibility test.
   - A fluid-based optimal scheduler.
   - (This followed directly from Agrawal et al.)

Correctness criterion CC-2 — insights

CC-2

Active LO-crit. jobs that have *started execution* get to keep their $C(\text{LO})$ budgets.

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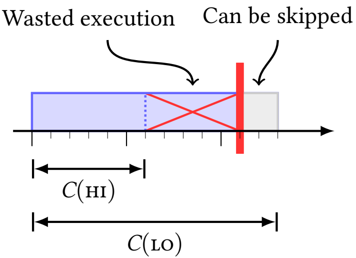
CC-1



Correctness criterion CC-2 — insights

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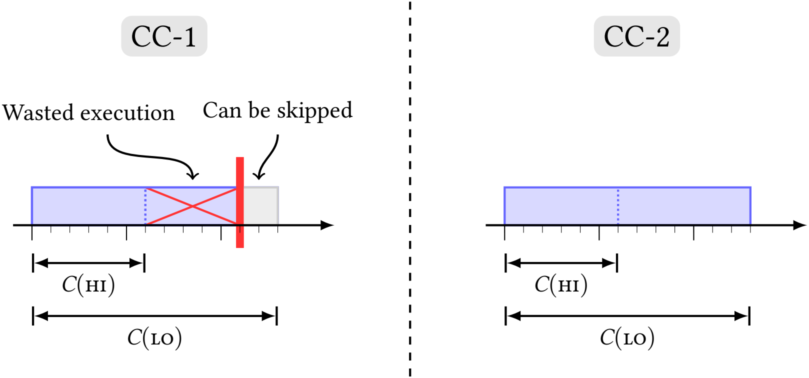

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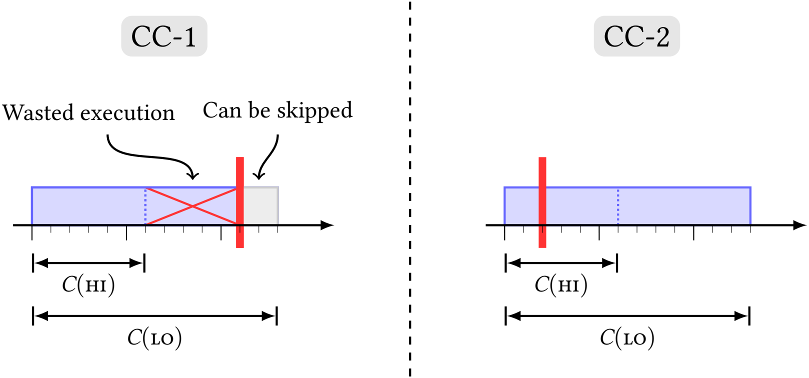

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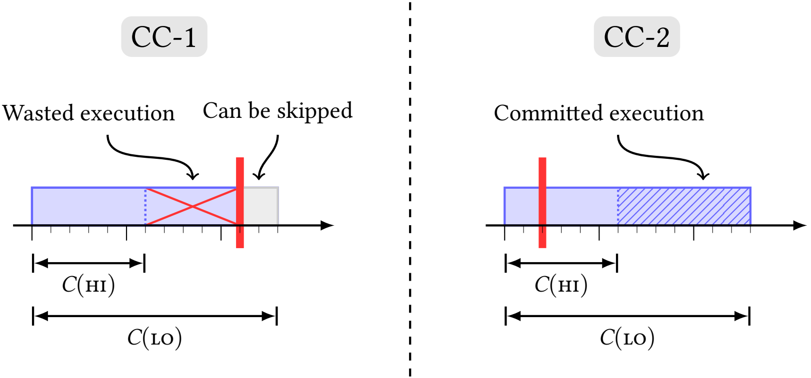

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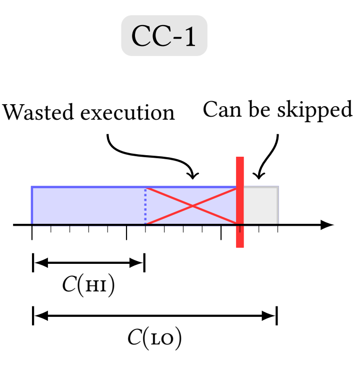

Correctness criterion CC-3 — insights

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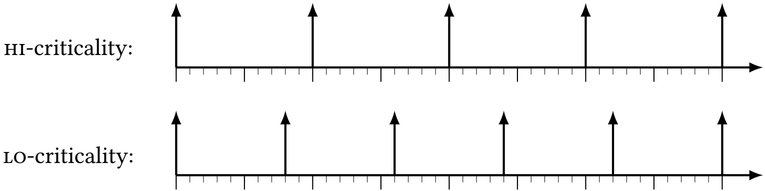

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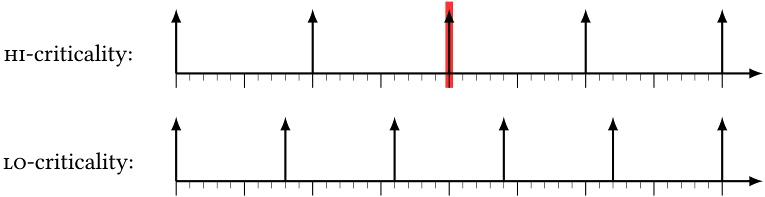

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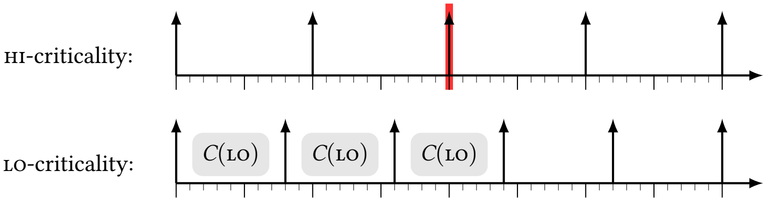

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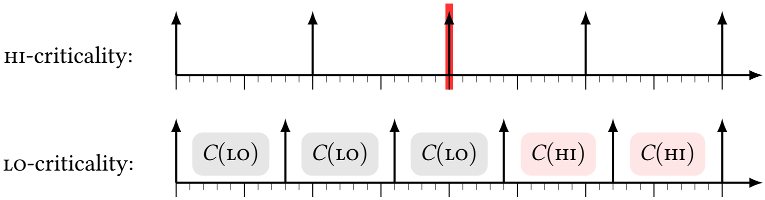

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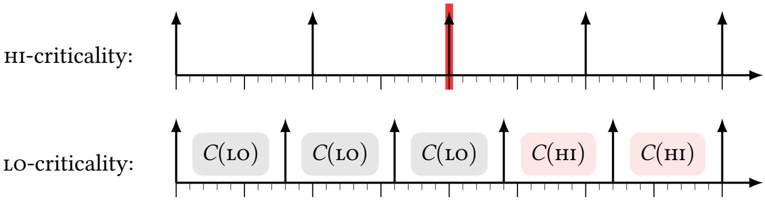

Observation

Under CC-3, the amount of execution time spent on each job is *independent* on the scheduling decisions.

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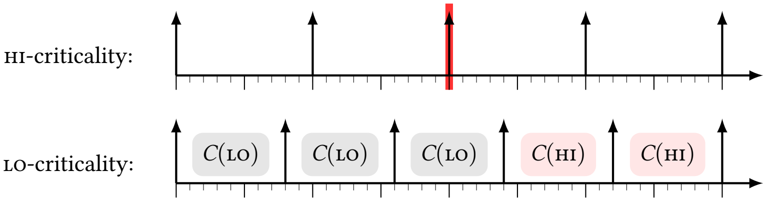

Observation

Under CC-3, the amount of execution time spent on each job is *independent* on the scheduling decisions.

$\Longrightarrow$ *EDF is an optimal scheduler* for both jobs and tasks!

CC-3 — RESULTS FOR JOBS

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Feasibility for *jobs* can be done in $O(n^2 \log n)$ time.

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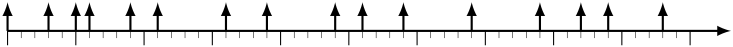

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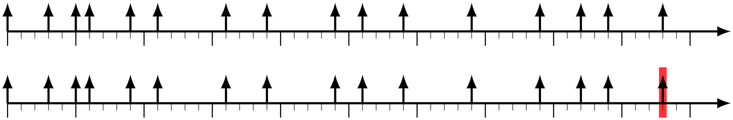

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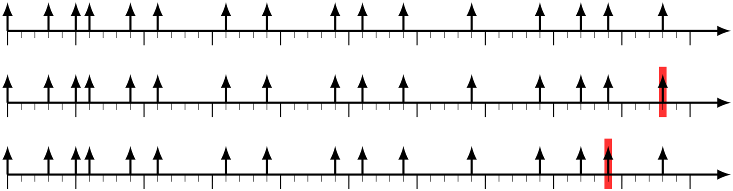

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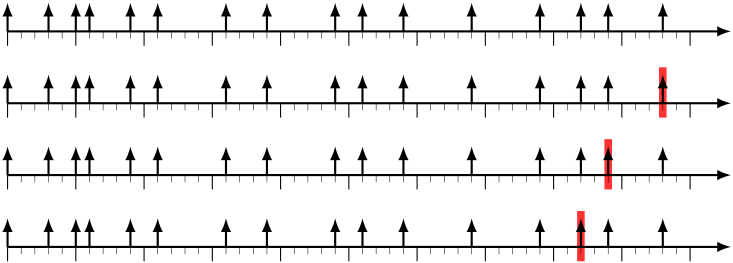

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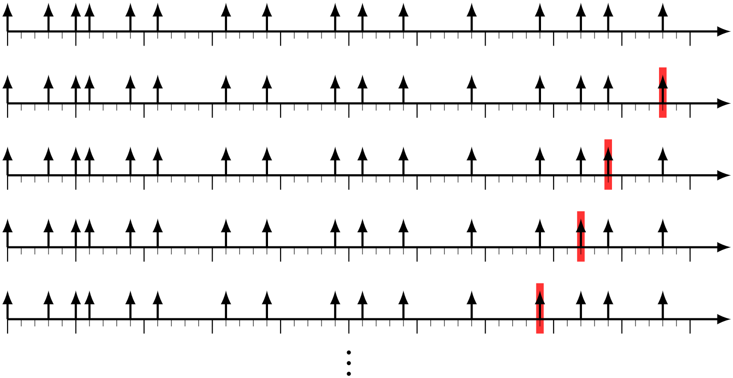

CC-3 — results for tasks

Tasks

Feasibility for *arbitrary-deadline sporadic tasks* can be done in pseudo-polynomial time if U is bounded by $c < 1$.

CC-3 — RESULTS FOR TASKS

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(Based on *dbf* analysis.)

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	CC-1	CC-2	CC-3
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$$\text{CC-3} \Longrightarrow \text{CC-2} \Longrightarrow \text{CC-1}$$

What is the modeling overhead?

The modeling overhead of CC-3

Over-approximating either CC-1 or CC-2 by CC-3 has a worst-case speedup cost of 2 (which is tight).

What is the modeling overhead?

The modeling overhead of CC-3

Over-approximating either CC-1 or CC-2 by CC-3 has a worst-case speedup cost of 2 (which is tight).

The modeling overhead of CC-2

Over-approximating CC-1 by CC-2 has a worst-case speedup cost in $[\varphi, 2]$. ($\varphi \approx 1.618$ is the golden ratio.)

$\forall$Thank you!

$\Diamond$

$\exists$Questions?