Scheduling and Analysis of Limited-Preemptive Malleable Gang Taks

Joan Marcè i Igual   Geoffrey Nelissen   Mitra Nasri   Paris Panagiotou

24th of February, 2020

What is gang?

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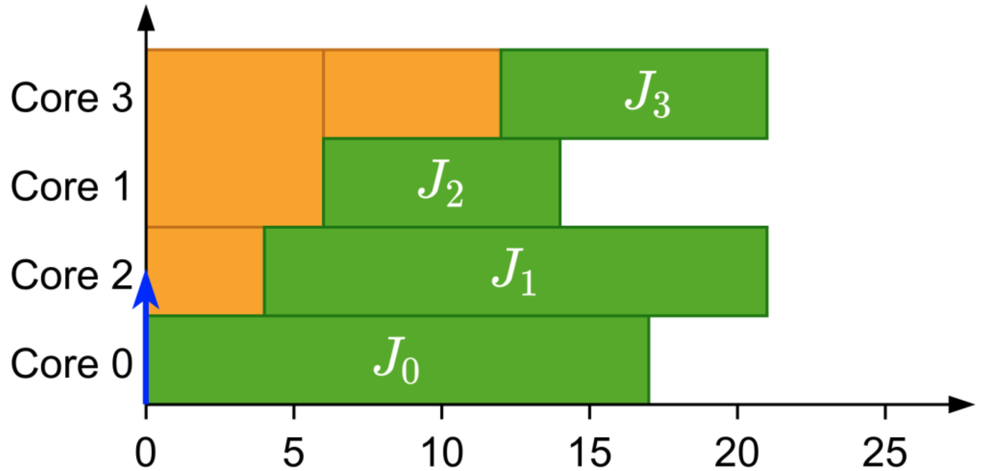
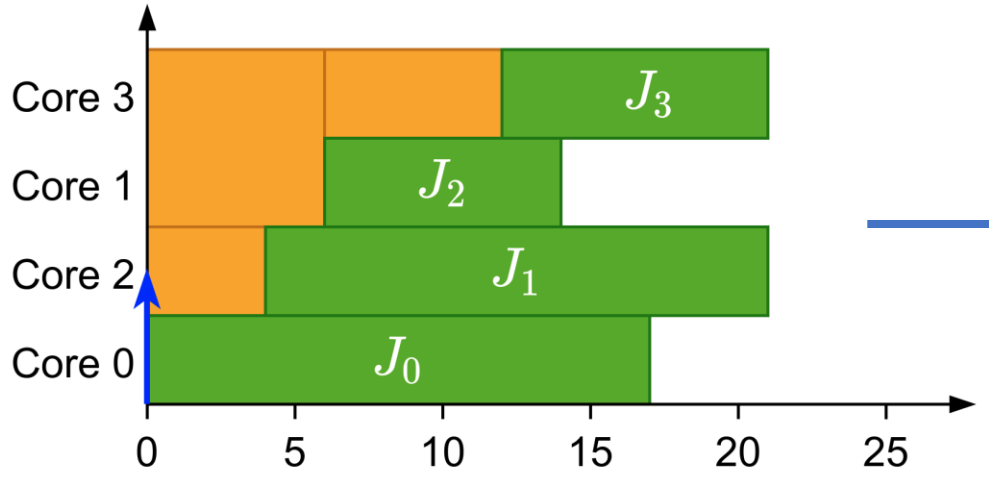


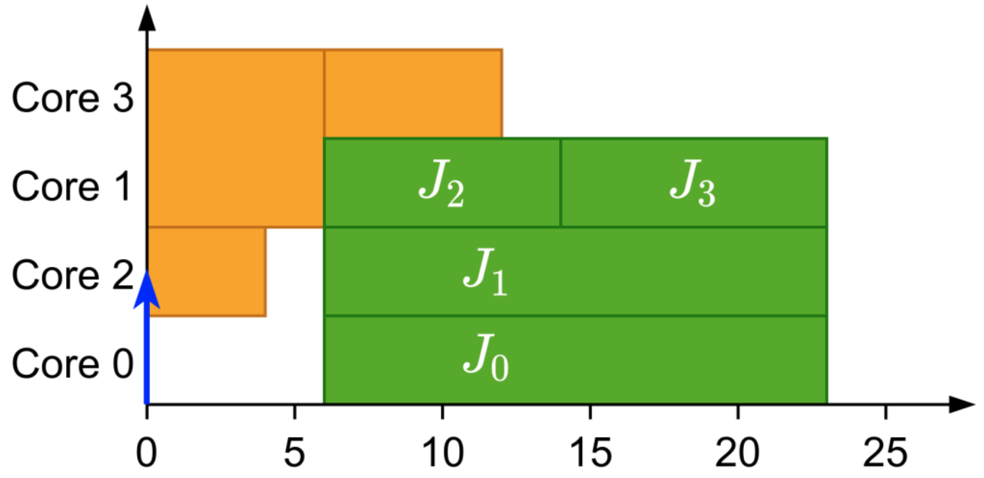
Global scheduling

What is gang?

- Parallel threads executed together as a "gang"



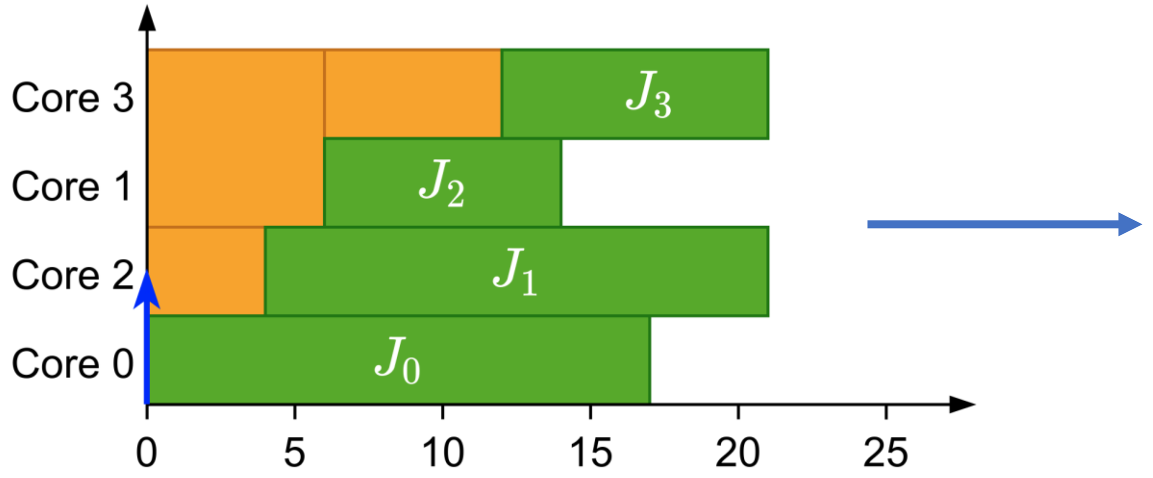
Global scheduling



Gang Scheduling

What is gang?

- Parallel threads executed together as a "gang"
- Execution does not start until there are enough free cores



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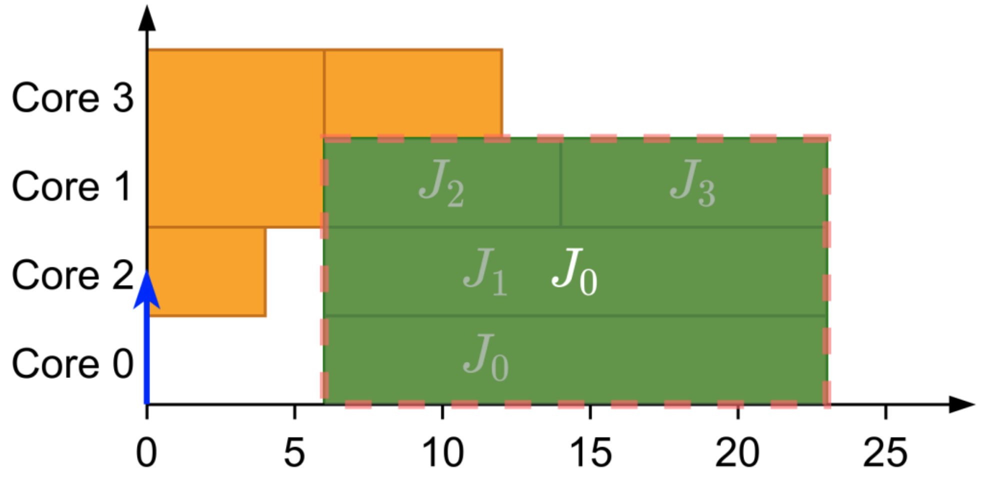

Gang Scheduling

Why gang?

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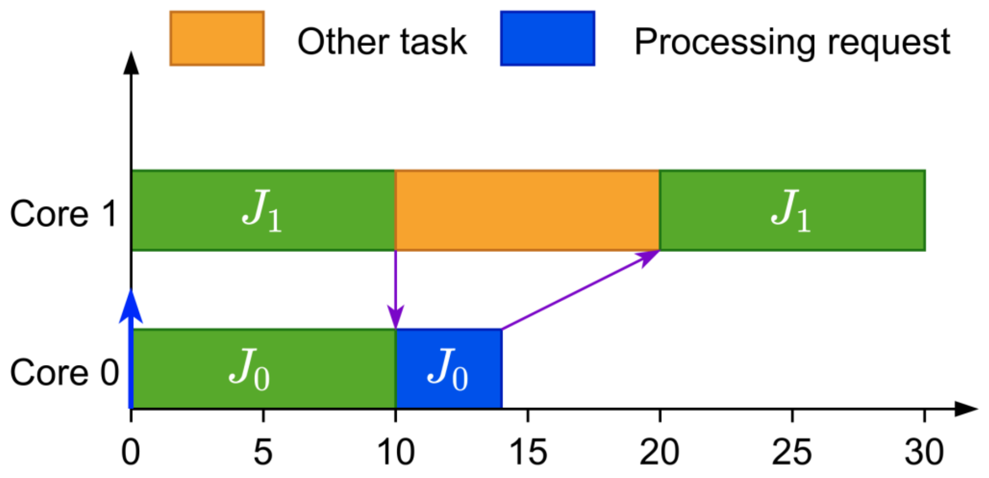
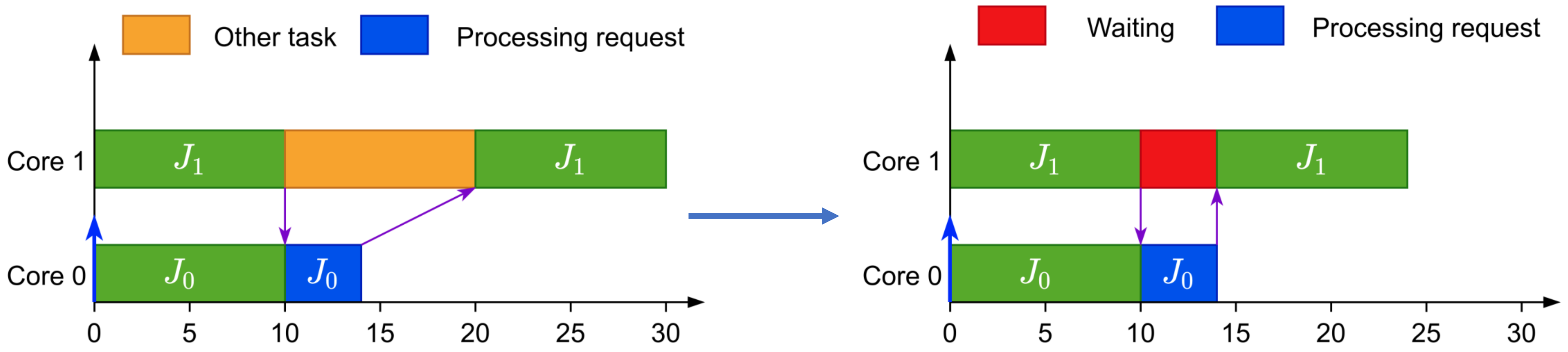


Other task
Processing request
Core 1
Core 0
J_1
J_1
J_0
J_0
0
5
10
15
20
25
30

Why gang?

- Efficient synchronization



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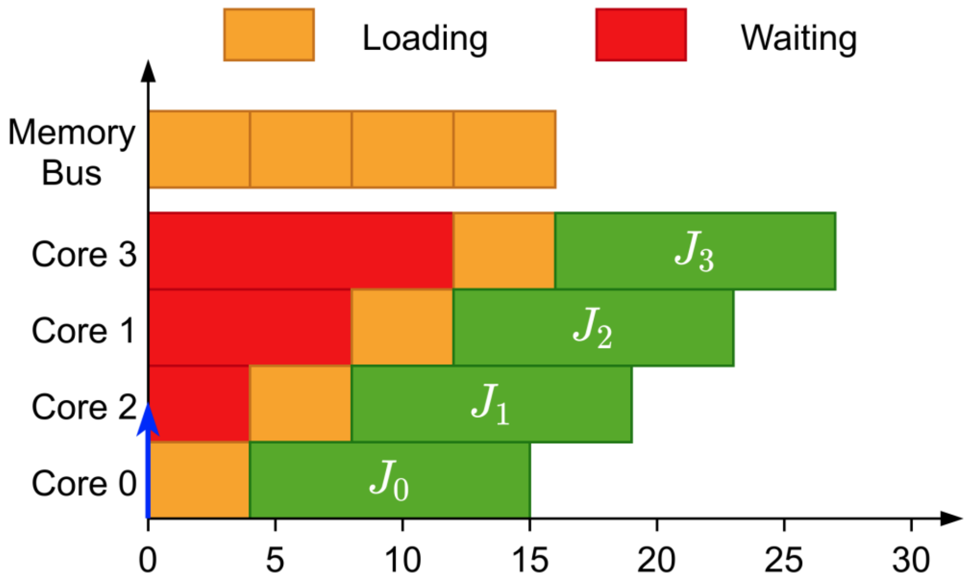

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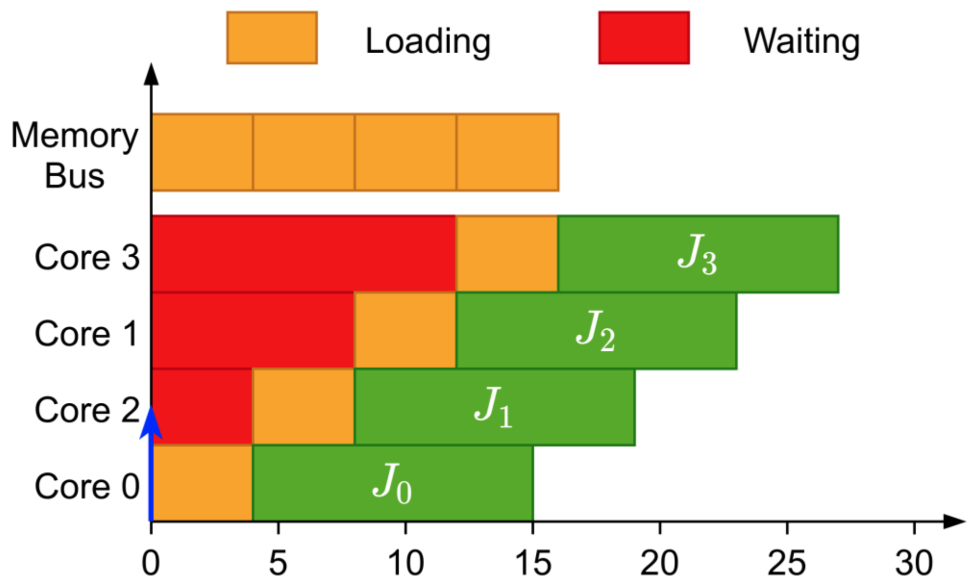

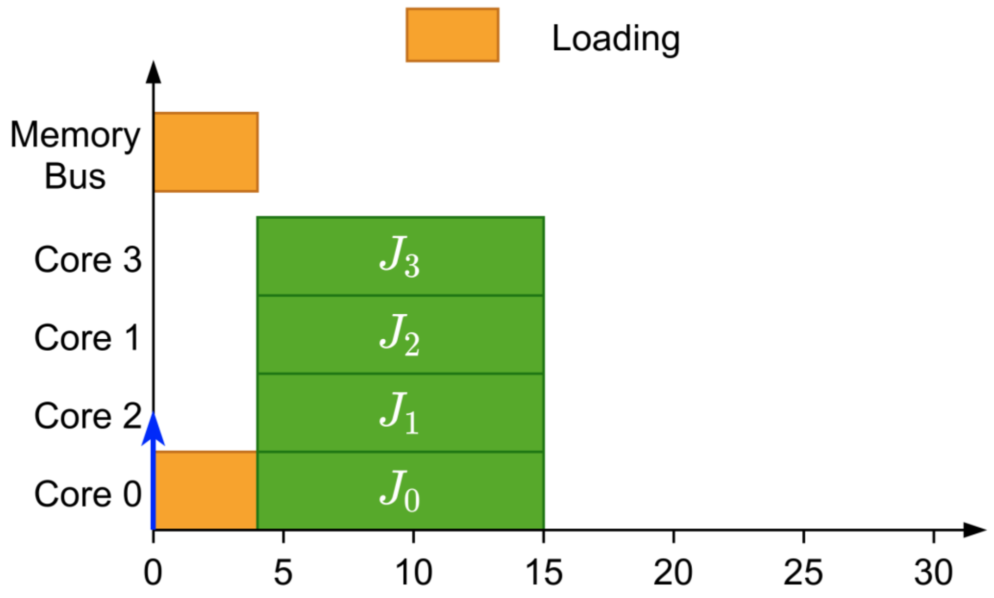

Types of gang

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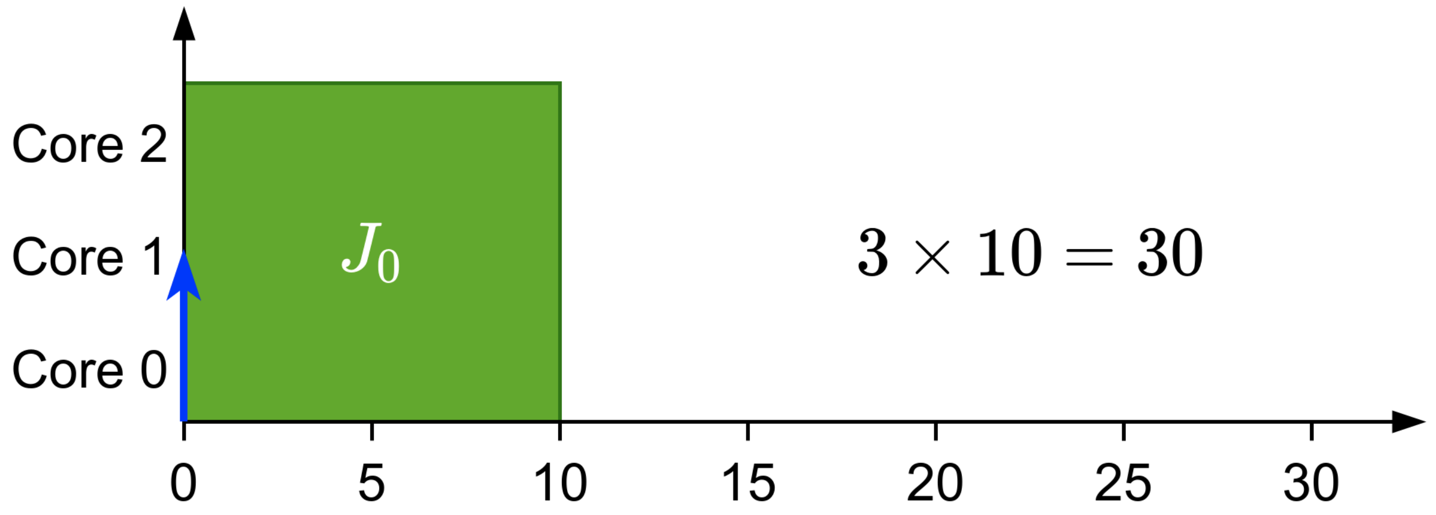
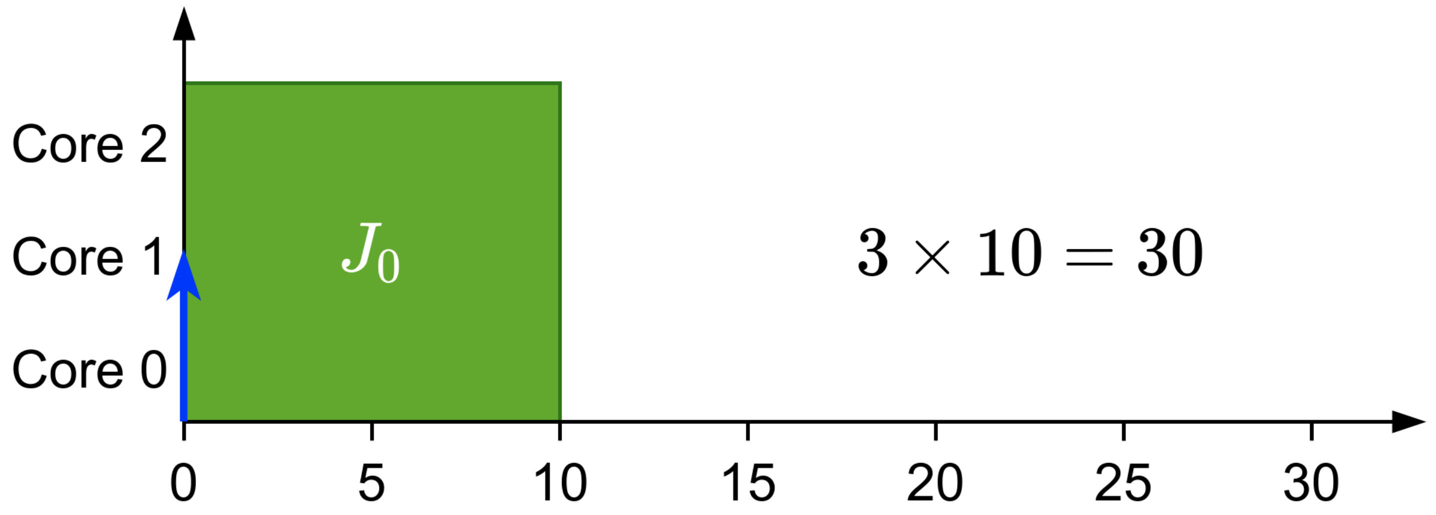


Types of gang

- **Rigid**: number of cores set by programmer



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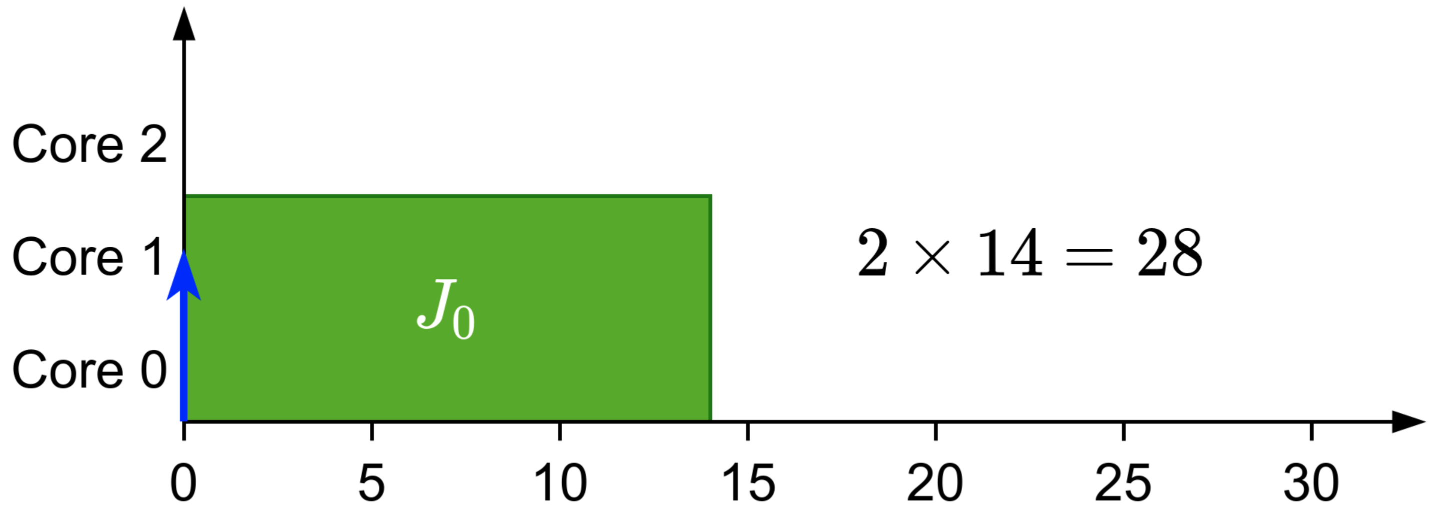

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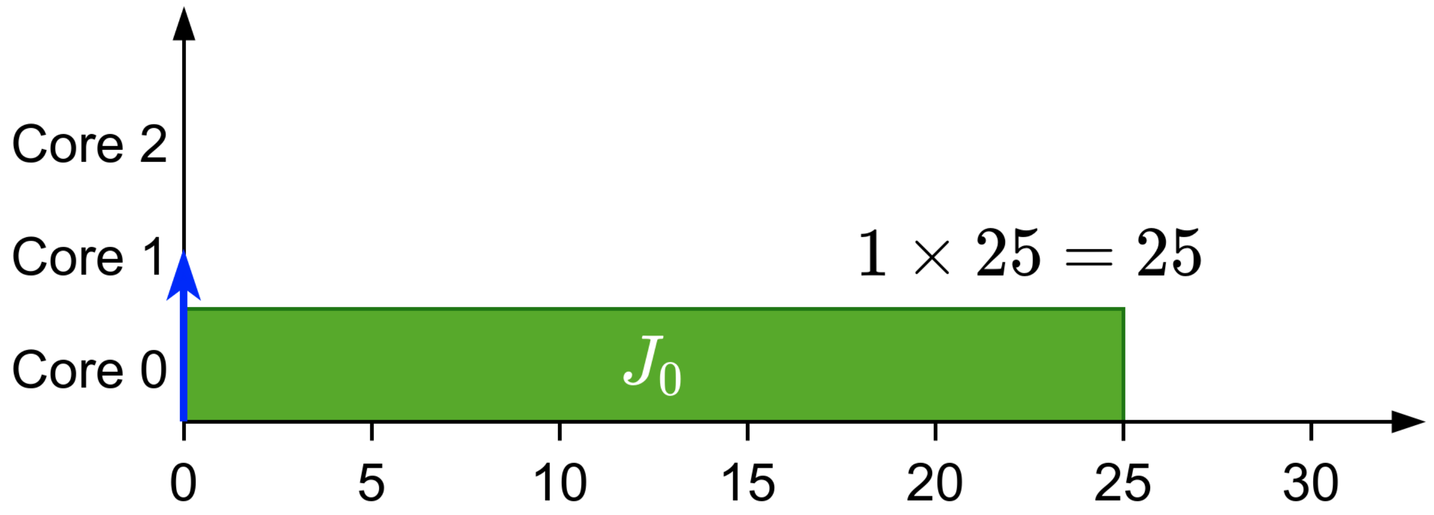

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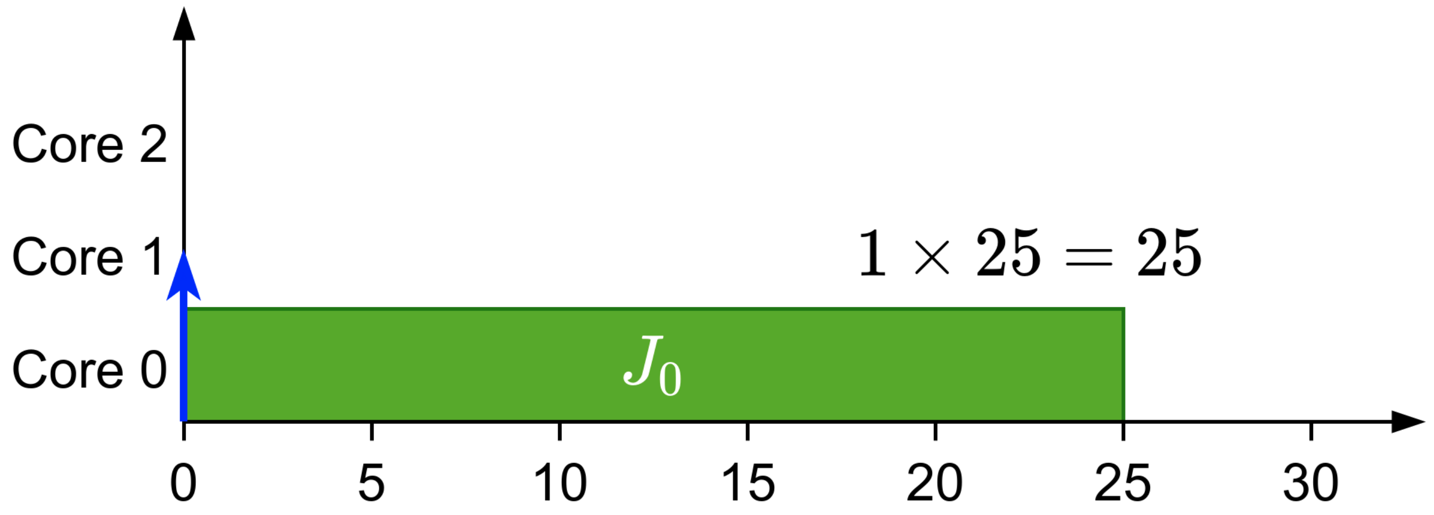
- **Moldable**: number of cores assigned during scheduling



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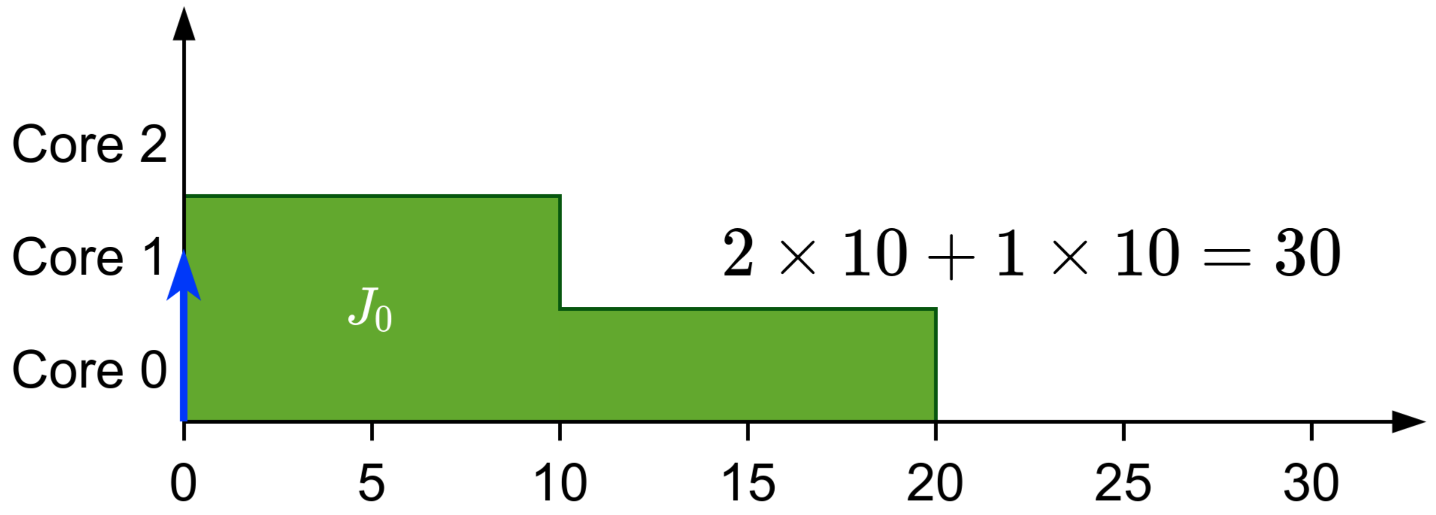

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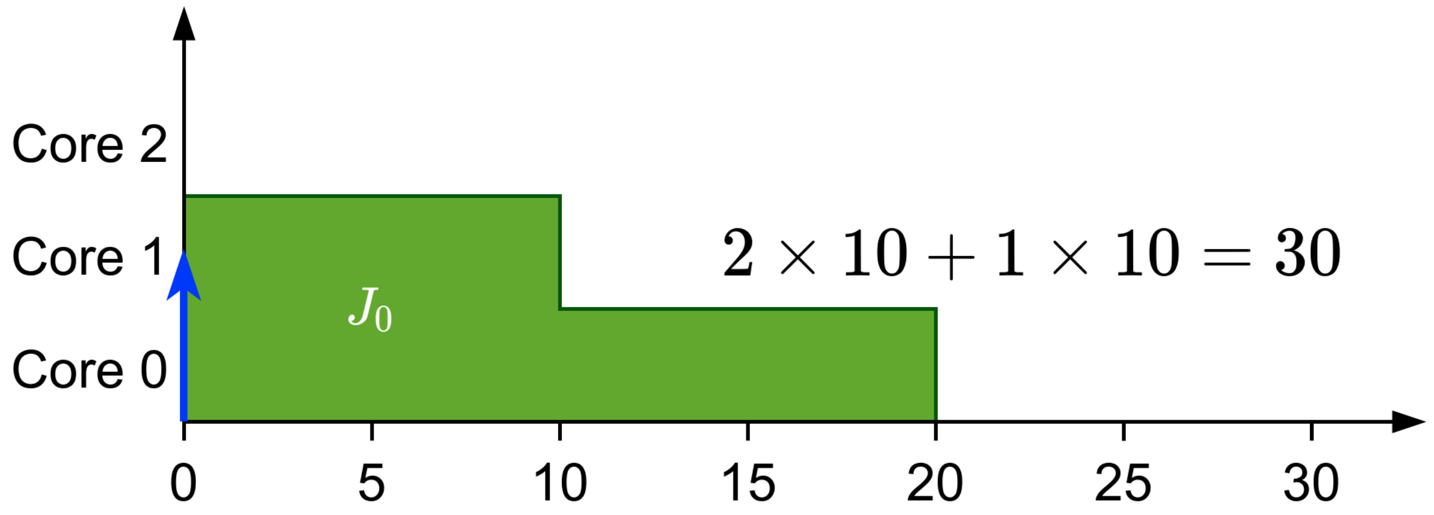

Previous work

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- Introduced in the context of high-performance computing[1]

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    - Moldable scheduler[4]
  - Bundled scheduling[5]
    - Tasks with precedence constraints modelled as a succession of bundles
    - Our limited-preemptive definition comes from here

[1]Ousterhout, 1982
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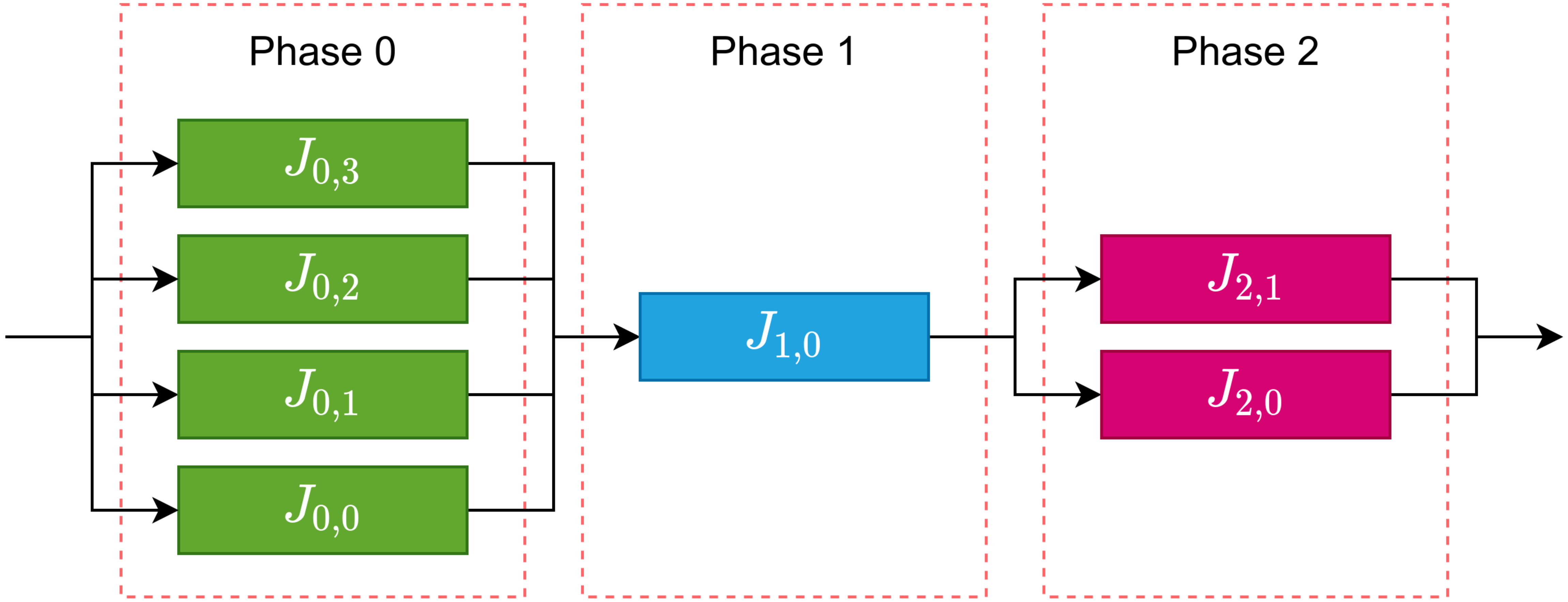
[4]Berten et al., 2011
[4]Wasly et al., 2017

Summarizing



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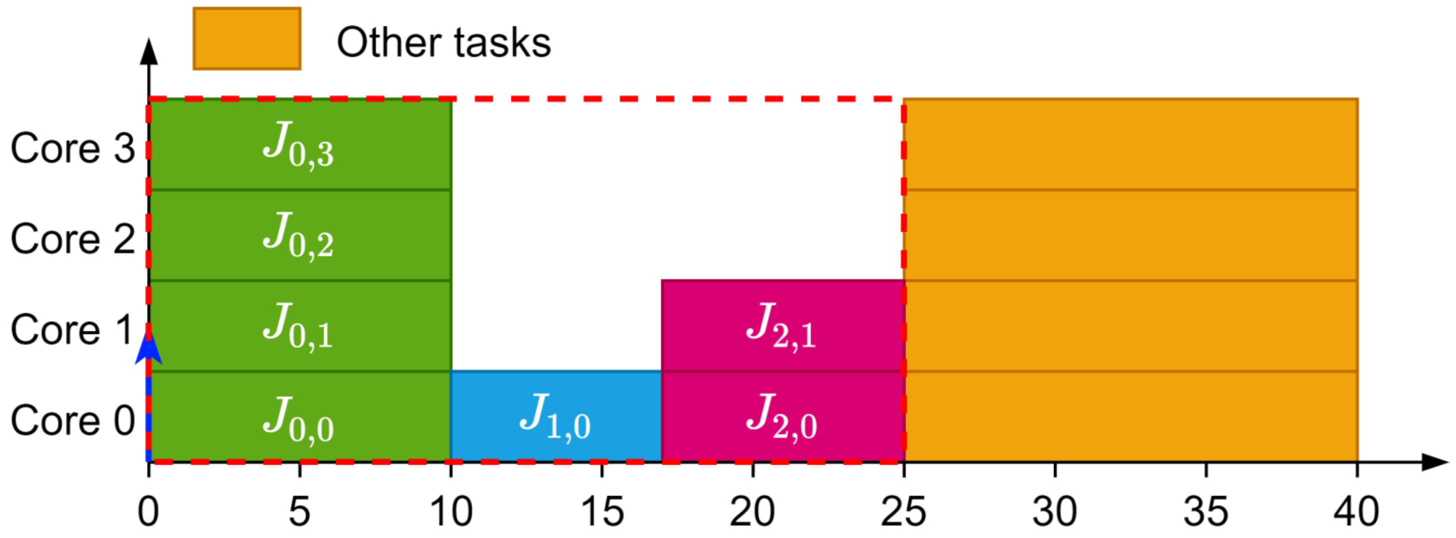
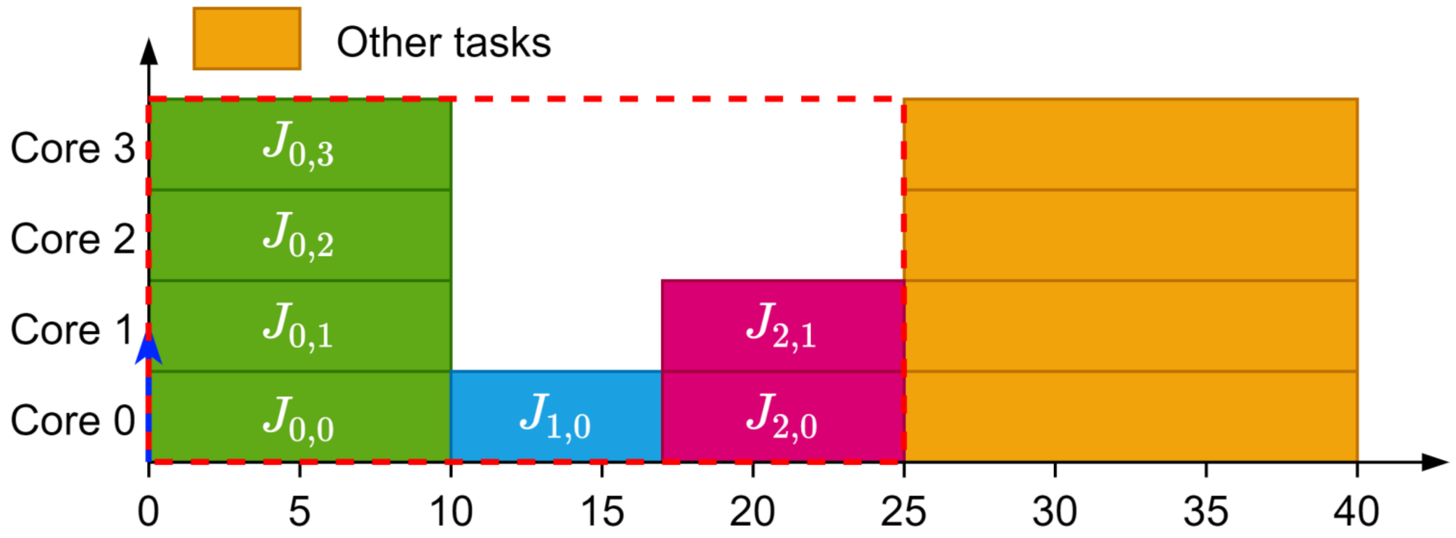


Rigid gang scheduling

Summarizing

- Rigid gang reserves the whole block



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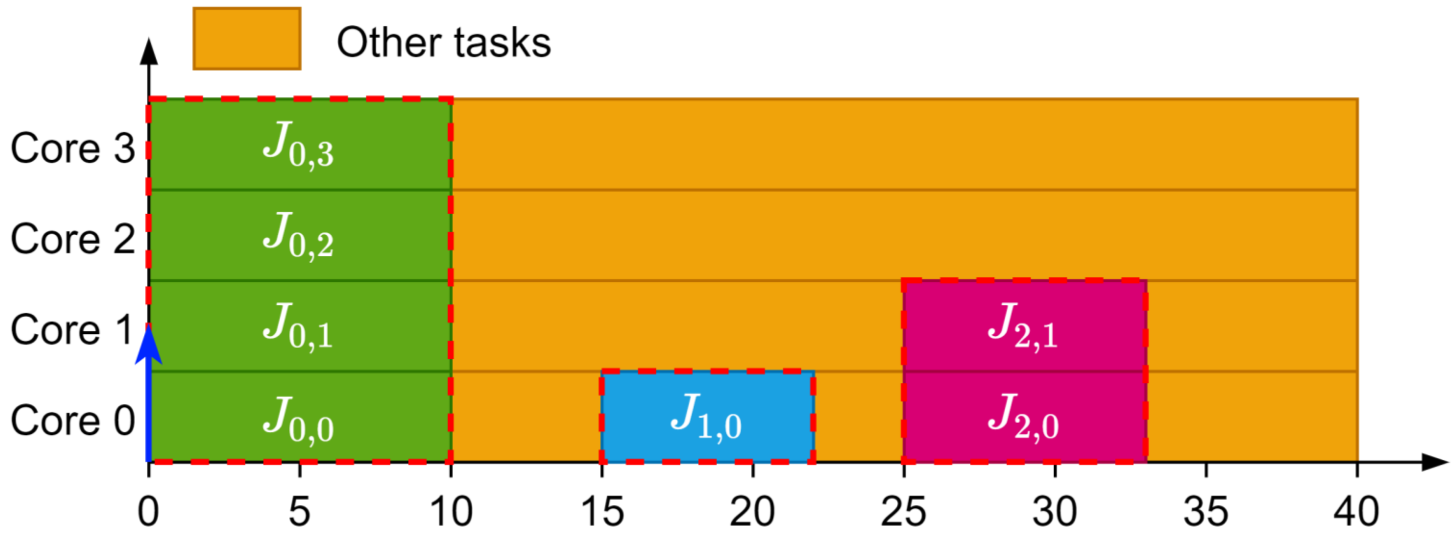

Bundled model scheduling

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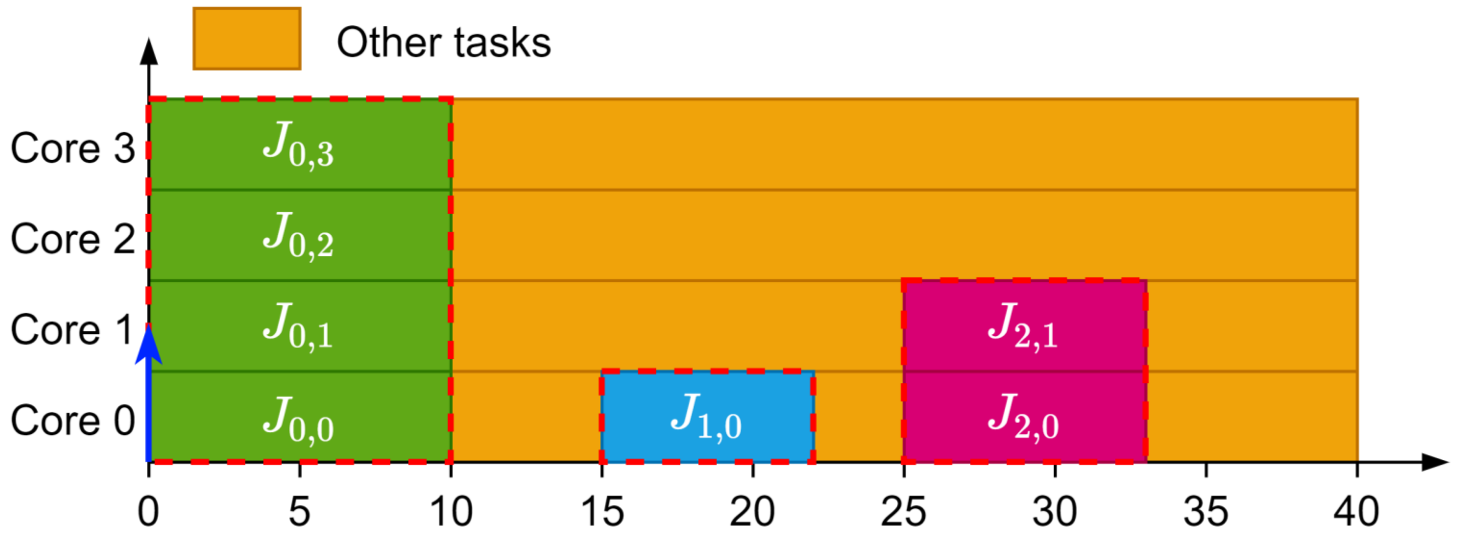
- Rigid gang reserves the whole block
- Bundled creates multiple rigid blocks with depencencies



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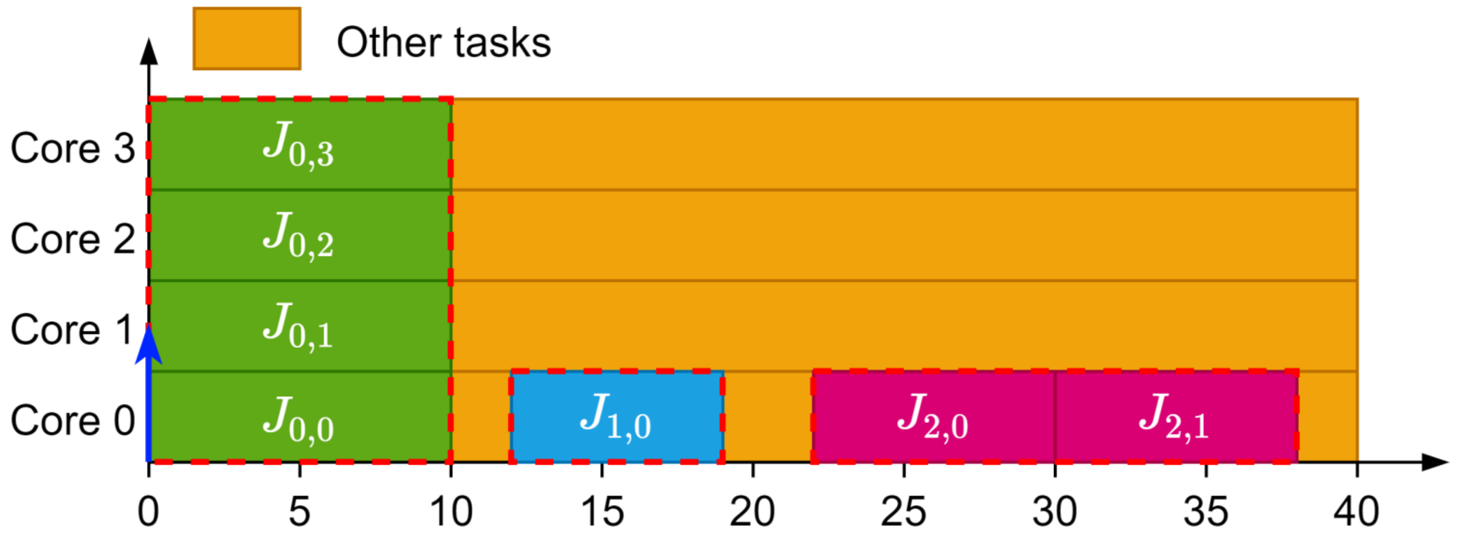
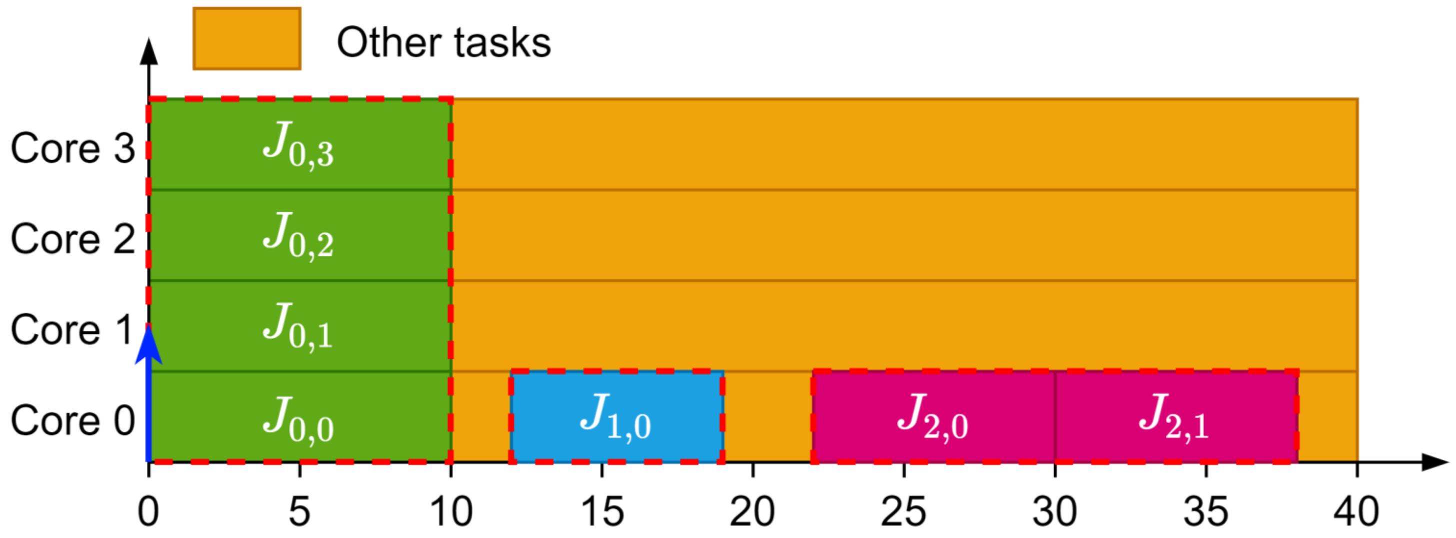


Limited-Preemptive scheduling

Summarizing

- Rigid gang reserves the whole block
- Bundled creates multiple rigid blocks with depencencies
- Limited-Preemptive tries to schedule these blocks in a moldable way



Limited-Preemptive scheduling

Our work

Project goals

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- Design an accurate schedulability analysis for limited-preemptive moldable gang tasks

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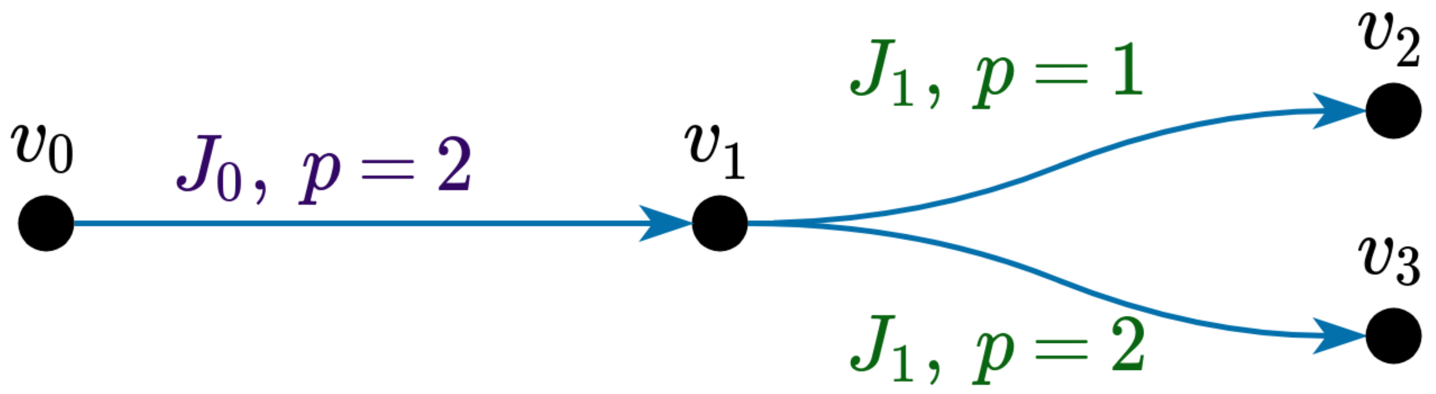
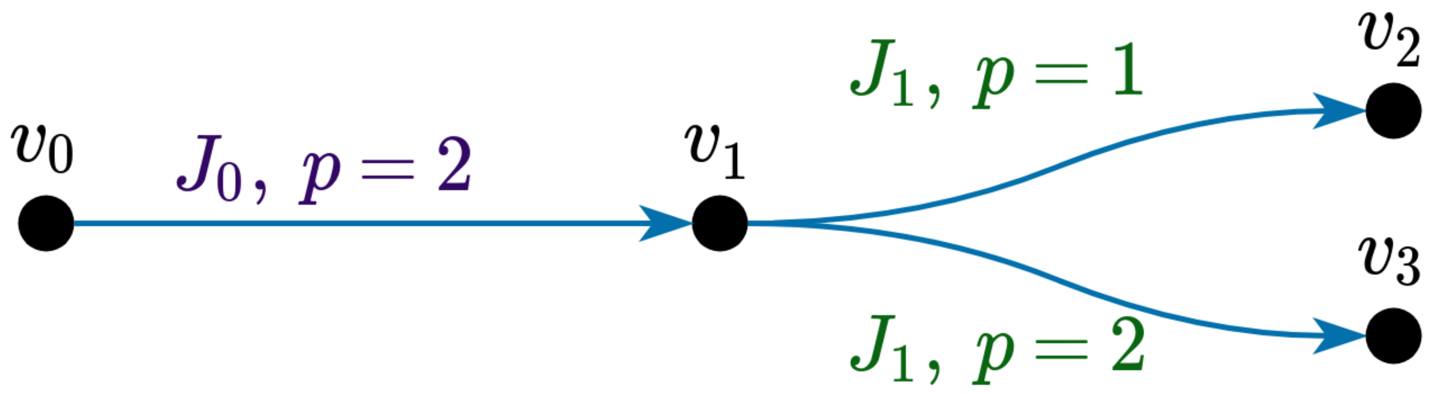
- Design an accurate schedulability analysis for limited-preemptive moldable gang tasks
- Propose a new scheduling algorithm to improve the schedulability of limited-preemptive moldable gang tasks

Schedule Abstraction Graph



Schedule Abstraction Graph

- Accurate and relatively fast analysis
  - Faster than an exact analysis
  - Not as pessimistic as closed-form analyses



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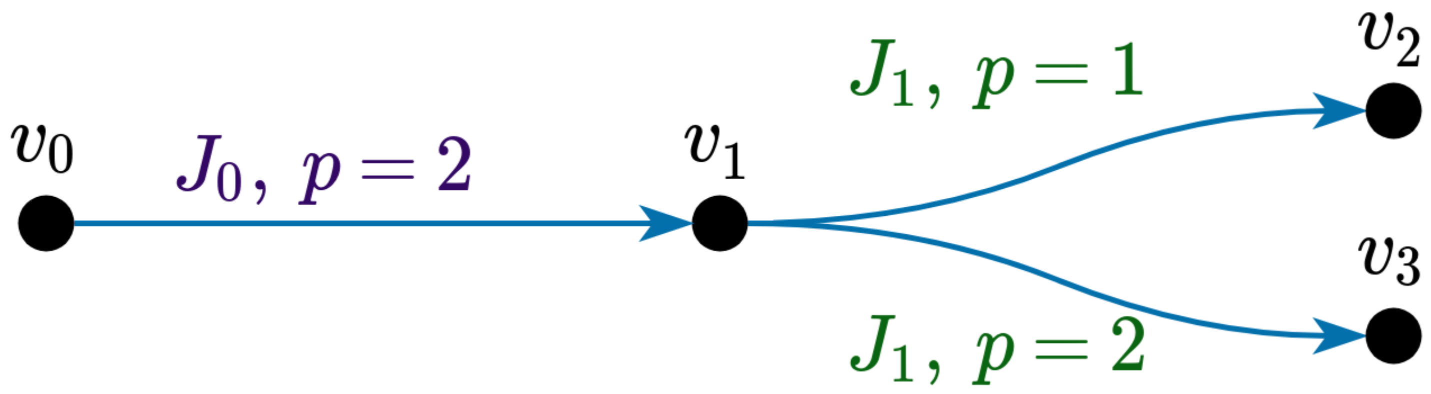
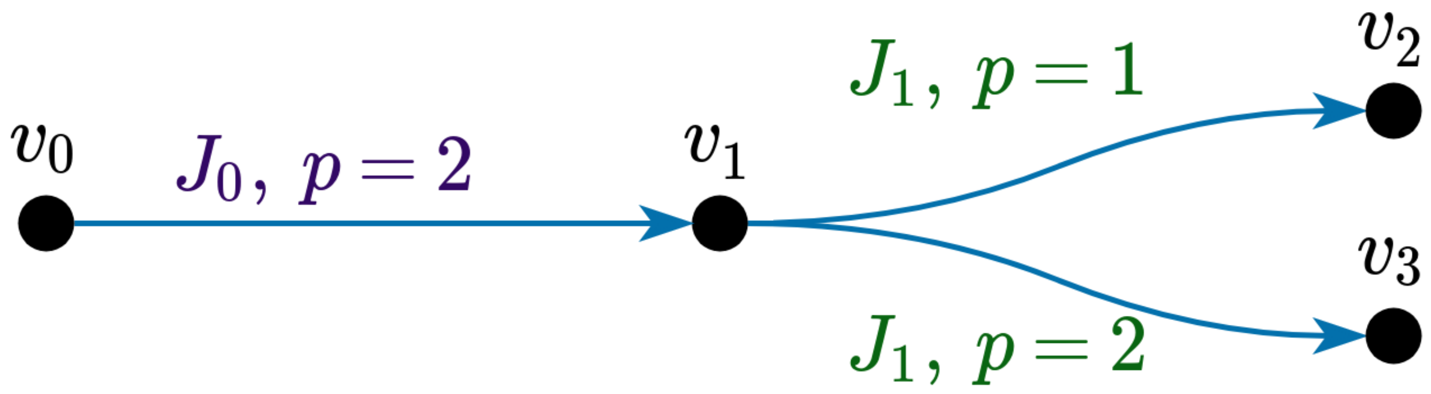


Schedule Abstraction Graph

- Accurate and relatively fast analysis
  - Faster than an exact analysis
  - Not as pessimistic as closed-form analyses
- Models scheduler decisions
- Encodes core availability after every transition


$$\begin{tikzcd} v_0 \arrow[r, "{J_0,\ p=2}"] & v_1 \arrow[r, bend left, "{J_1,\ p=1}"] \arrow[r, bend right, "{J_1,\ p=2}"'] & v_2 \ / \ v_3 \end{tikzcd}$$

Job-Level Fixed Priority Scheduler for Gang

- Based on Global JLFP scheduler
- Work conserving scheduler
- Job with highest priority goes first
- Assigns maximum cores available between $s_i^{\min}$ and $s_i^{\max}$

Difficulties related to SAG

- We have to consider all scenarios.
- The scheduler has to decide:
  - When to release a job
  - How many cores to assign to this job

Analysis

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- $A_c^{\min}$ time at which we have c cores possibly available
- $A_c^{\max}$ time at which we have c cores certainly available

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- LST_i Latest Start Time
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$$EST_i \leq LST_i$$

TU Delft

Analysis

- $A_c^{\min}$ time at which we have c cores possibly available
- $A_c^{\max}$ time at which we have c cores certainly available

- EST_i^p Earliest Start Time
- LST_i^p Latest Start Time
- EFT_i^p Earliest Finishing Time
- LFT_i^p Latest Finishing Time

$$EST_i^p \leq LST_i^p$$

Analysis

$$EST_i^p = \max\{r_i^{\min}, A_p^{\min}\}$$

- Job cannot start before
  - Being released
  - Enough cores are available

$$LST_i^p = \min\{t_{p+1}, t_{wc}, t_{high} - 1\}$$

- Job cannot start with p cores after:
  - $p + 1$ cores are available as JLFP would schedule it with $p + 1$ cores
  - A lower priority task is ready because JLFP is work-conserving
  - A higher priority task is ready

Analysis

- Obtain EFT_i^p and LFT_i^p from:

$$EFT_i^p = EST_i^p + c_i^{\min}(p)$$
$$LFT_i^p = LST_i^p + c_i^{\max}(p)$$

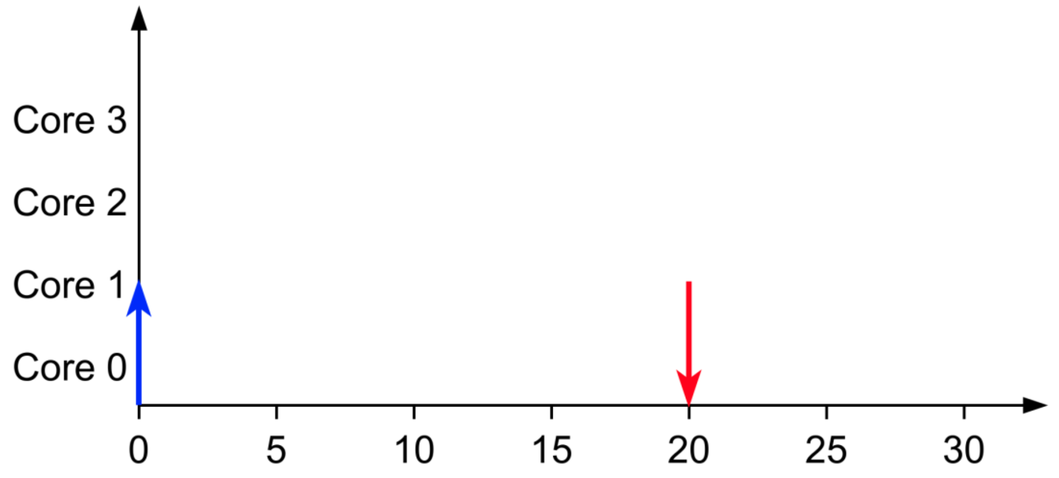
- And compute new $A_c^{\min}$ and $A_c^{\max}$

New scheduler

LPMRGS

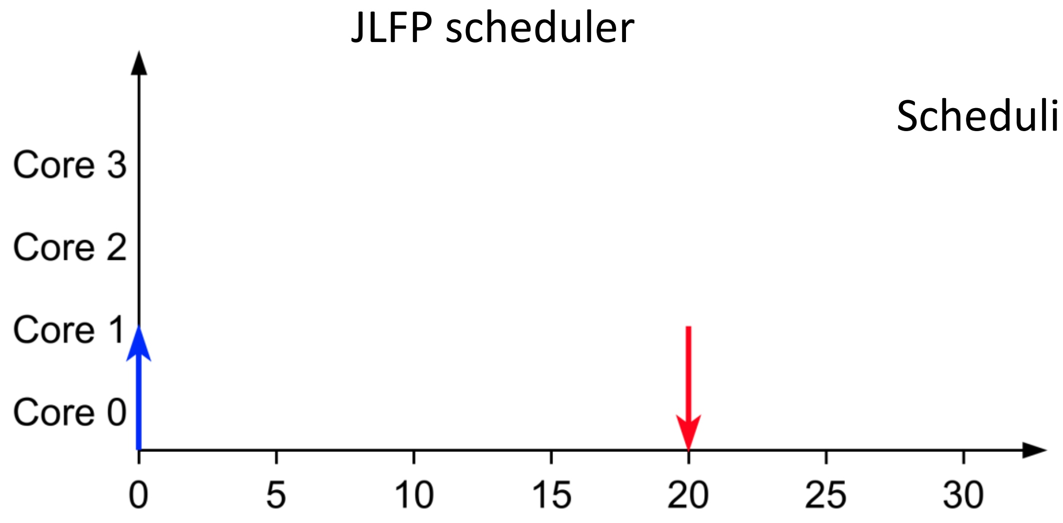
LPMRGS

JLFP scheduler



	$s_j^{\min}$	$s_j^{\max}$	d_i	$c_i(v)$
J_0	2	2	100	10
J_1	3	3	20	5
J_2	1	1	100	20
J_3	1	3	100	24, 13, 20

LPMRGS



Scheduling: J_0

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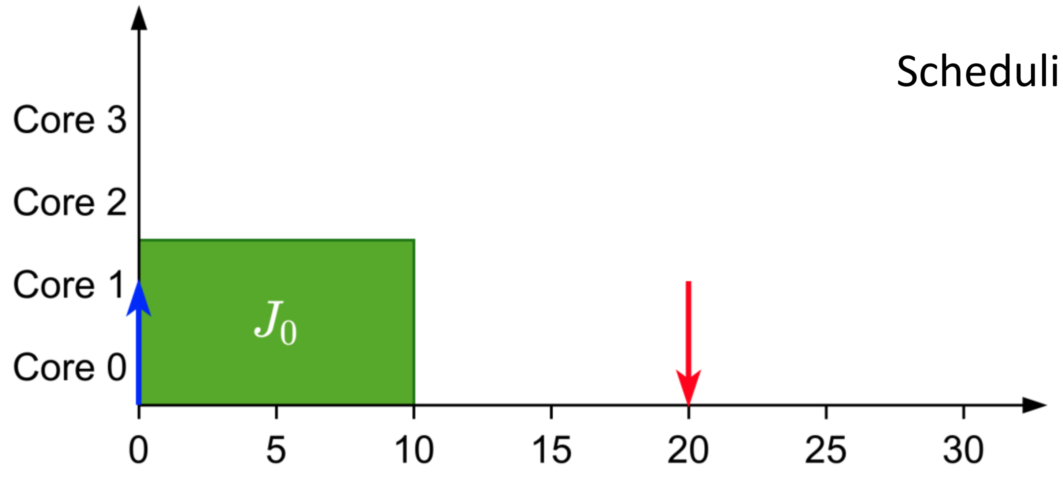

Scheduling: J_1

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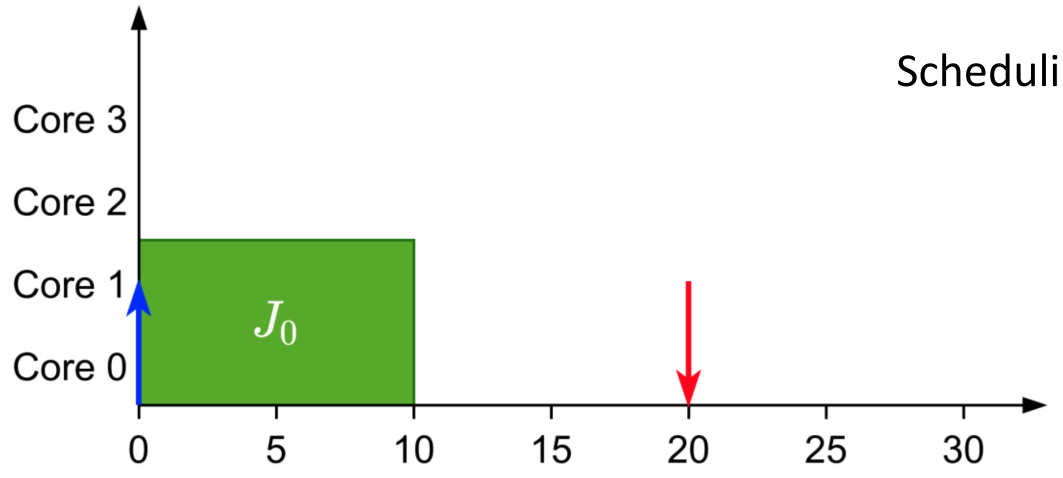

Scheduling: J_2

	$s_j^{\min}$	$s_j^{\max}$	d_i	$c_i(v)$
J_0	2	2	100	10
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LPMRGS

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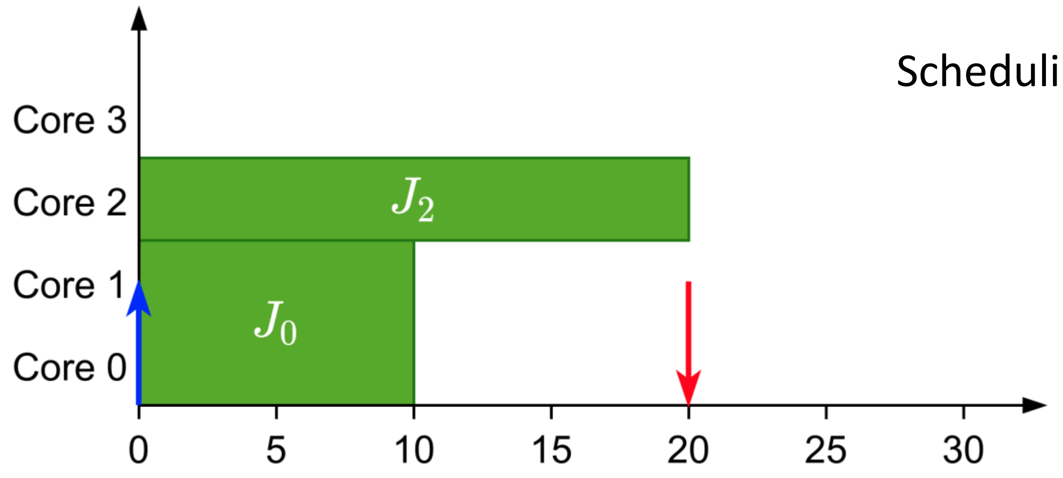

Scheduling: J_3

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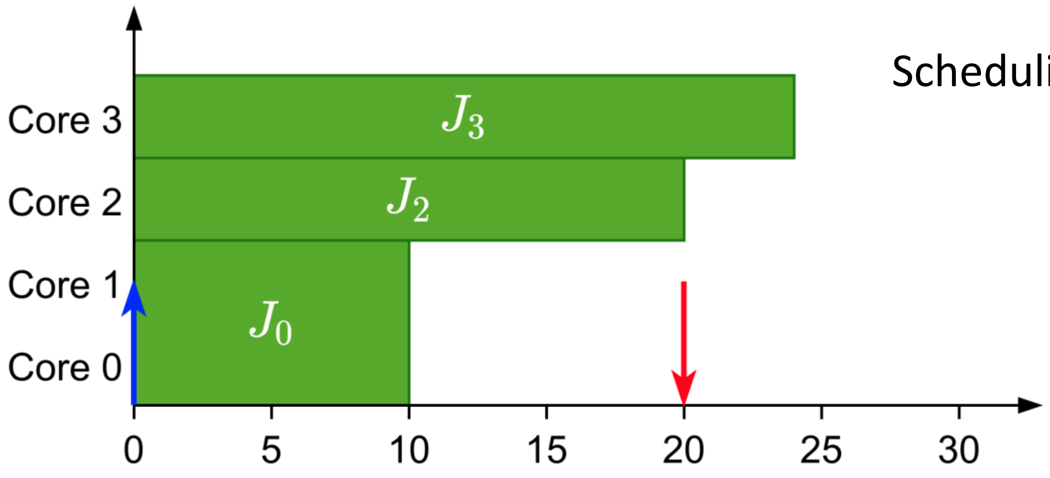

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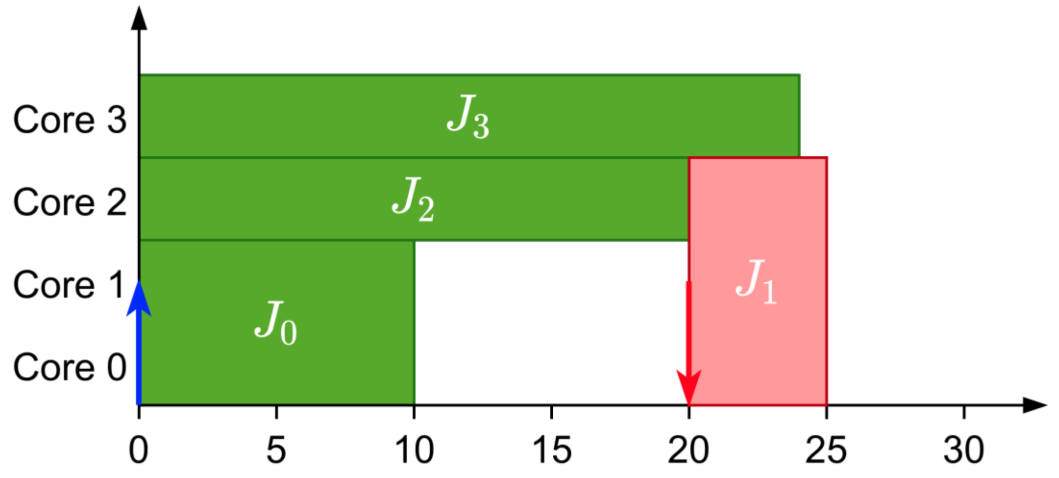

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LPMRGS

- Limited-Preemptive Moldable Reservation Gang Scheduler
- Non-work conserving scheduler
- Reserve cores of higher-priority tasks and distribute the remaining ones among lower priority tasks

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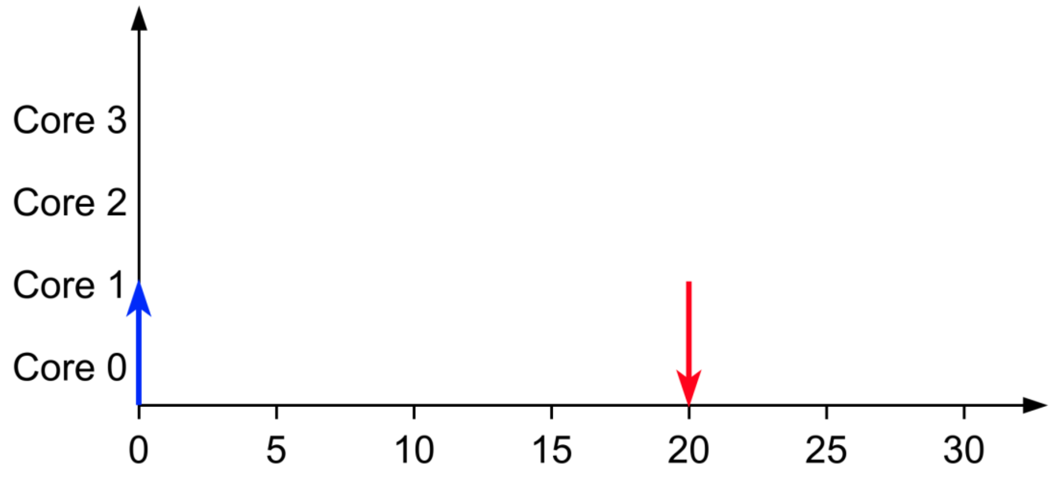

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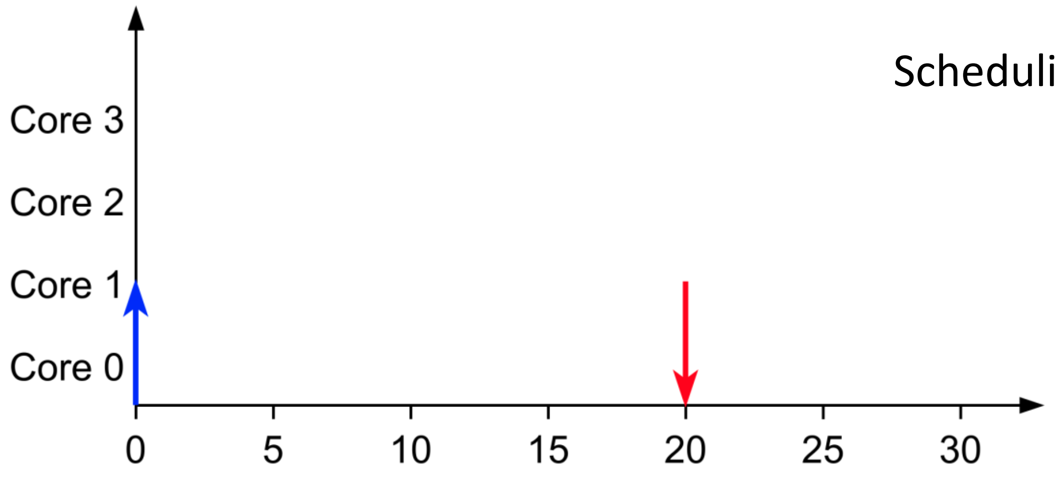

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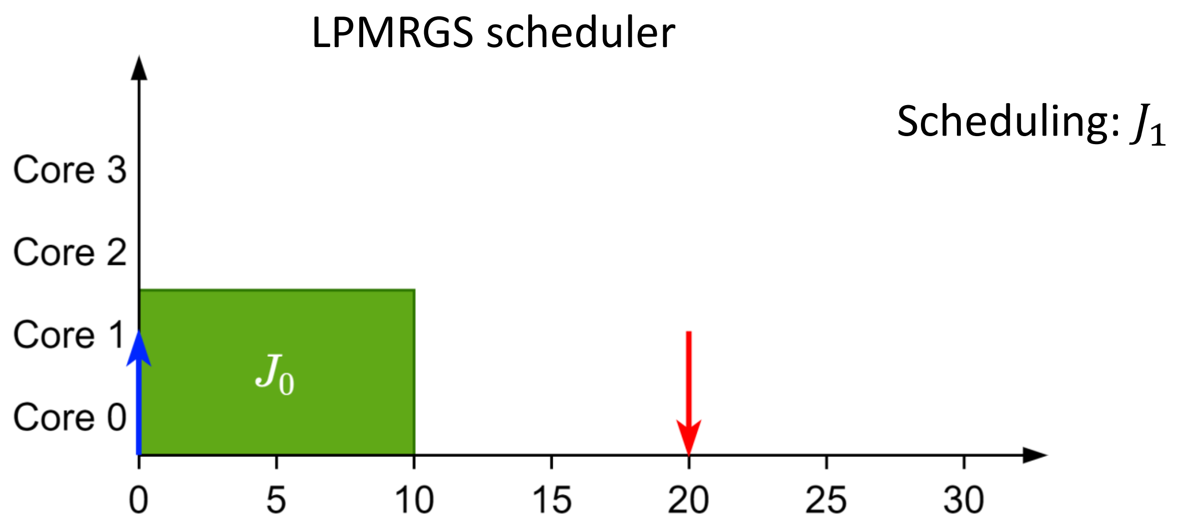

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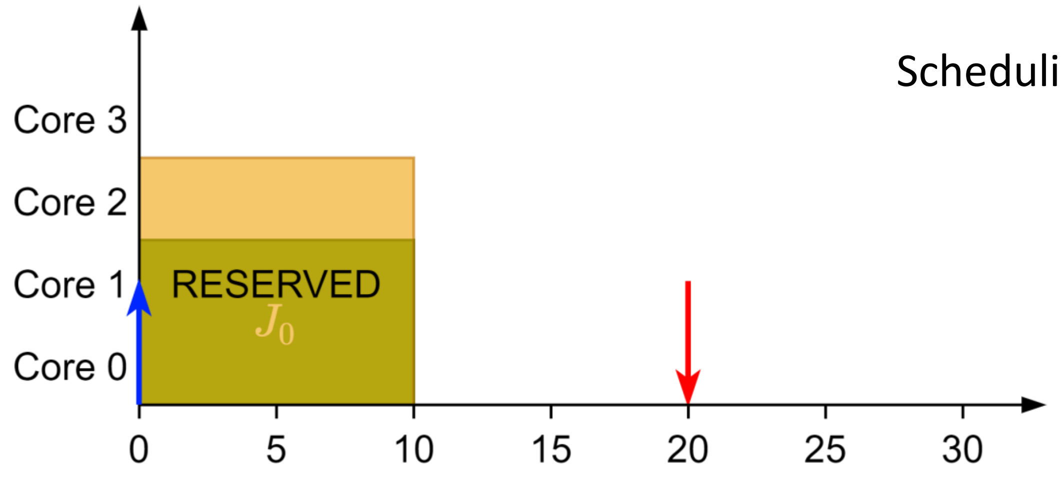

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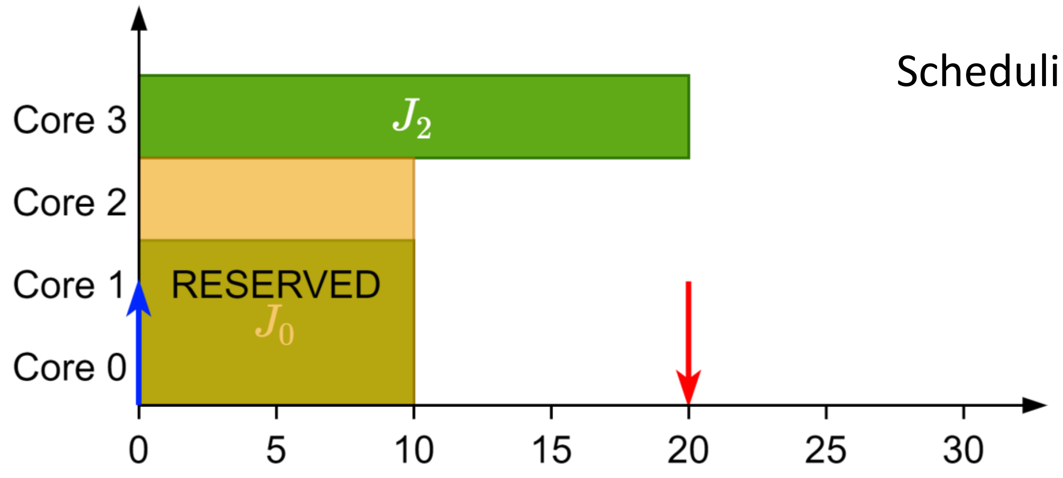

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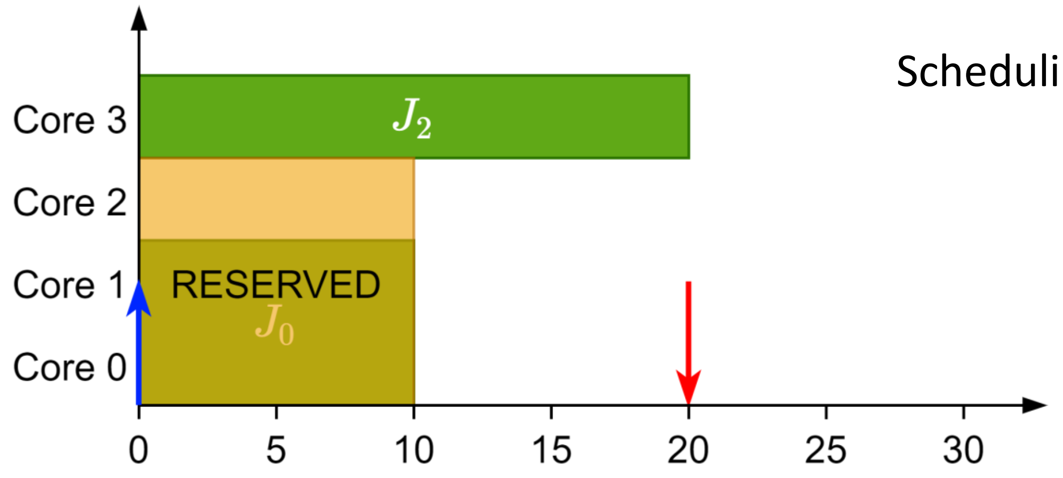

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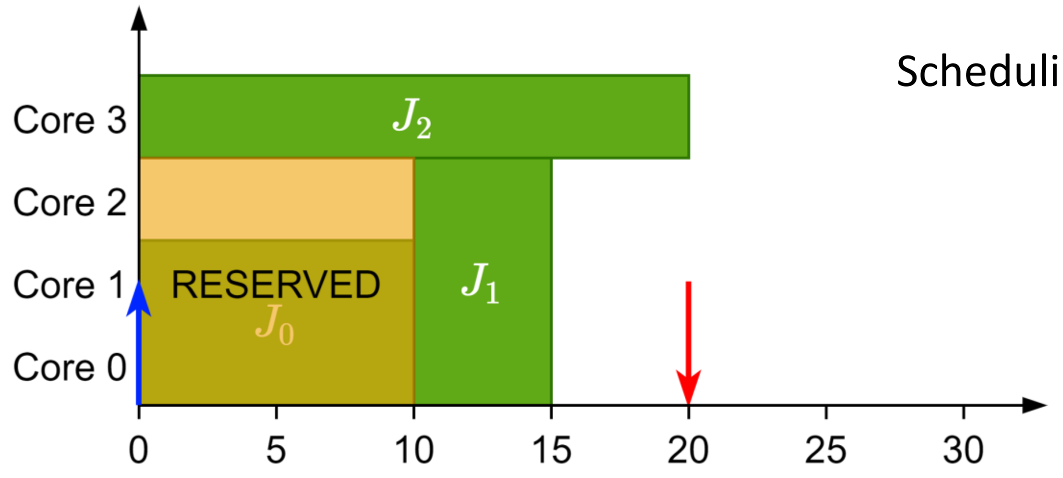
LPMRGS scheduler



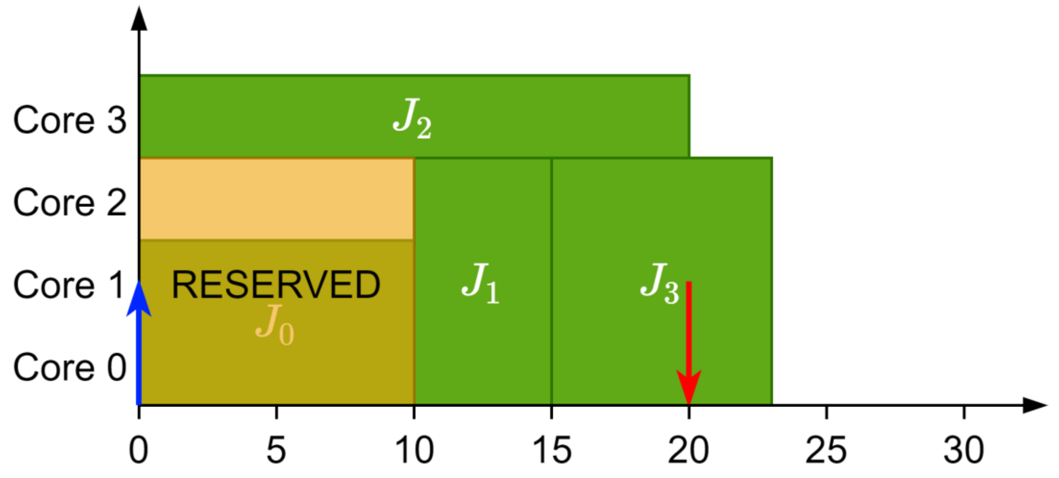
Scheduling: J_3

	$s_j^{\min}$	$s_j^{\max}$	d_i	$c_i(v)$
J_0	2	2	100	10
J_1	3	3	20	5
J_2	1	1	100	20
J_3	1	3	100	24, 13, 20

LPMRGS

- Limited-Preemptive Moldable Reservation Gang Scheduler
- Non-work conserving scheduler
- Reserve cores of higher-priority tasks and distribute the remaining ones among lower priority tasks

LPMRGS scheduler



	$s_j^{\min}$	$s_j^{\max}$	d_i	$c_i(v)$
J_0	2	2	100	10
J_1	3	3	20	5
J_2	1	1	100	20
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Questions?