Scheduling Self-Suspending Tasks: New and Old Results

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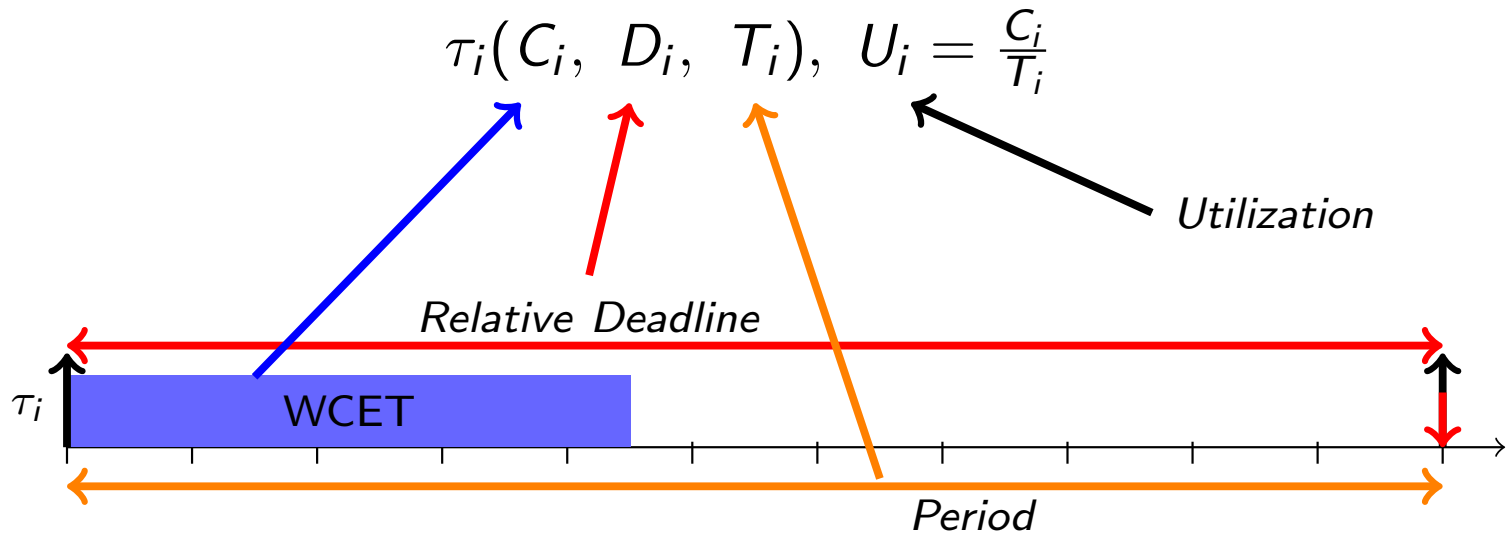
Sporadic Task Model



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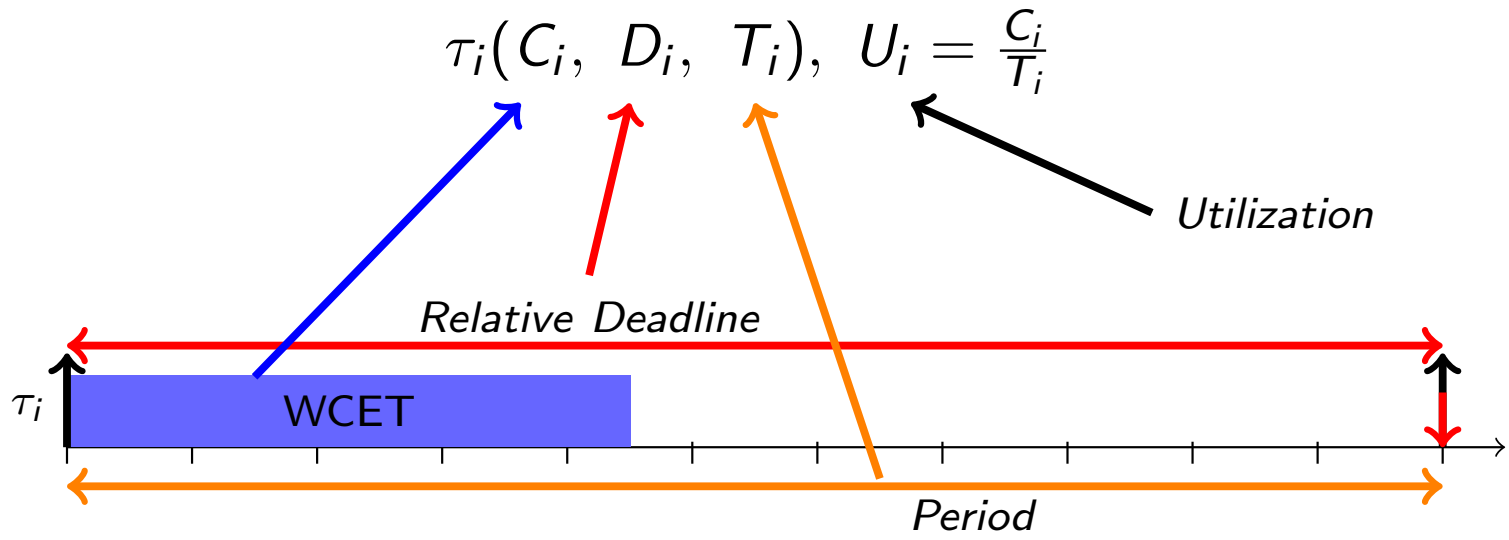
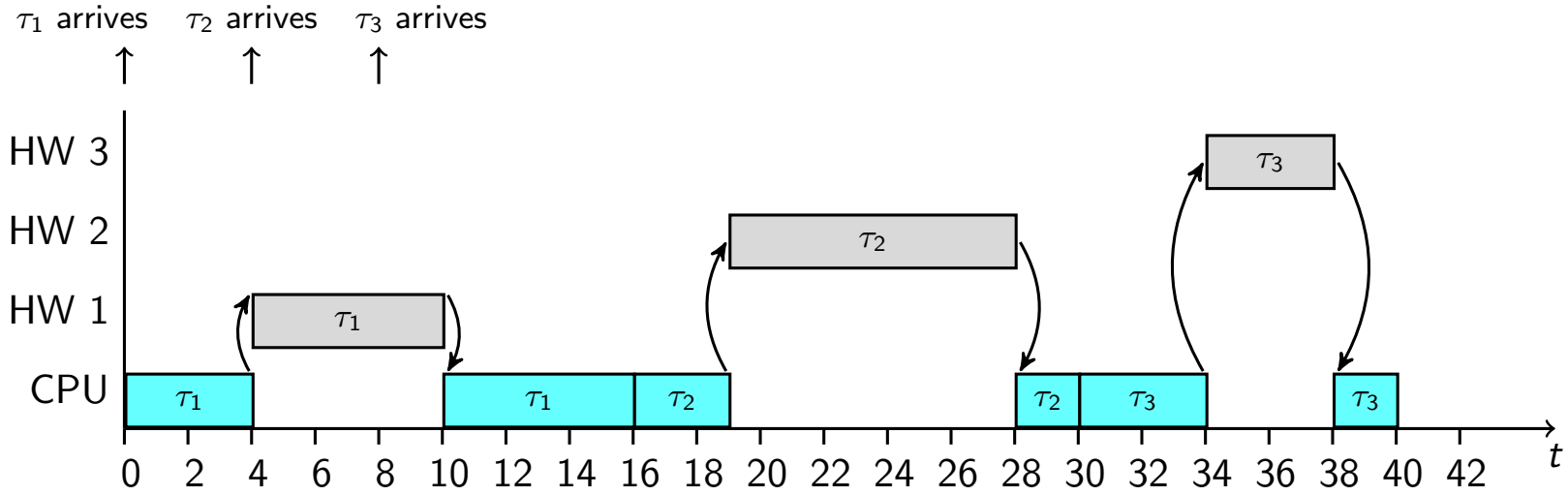


- Assumption: tasks do not voluntarily suspend themselves

Reasons for Suspension: Hardware Acceleration

Not use FPGA in parallel (busy waiting)



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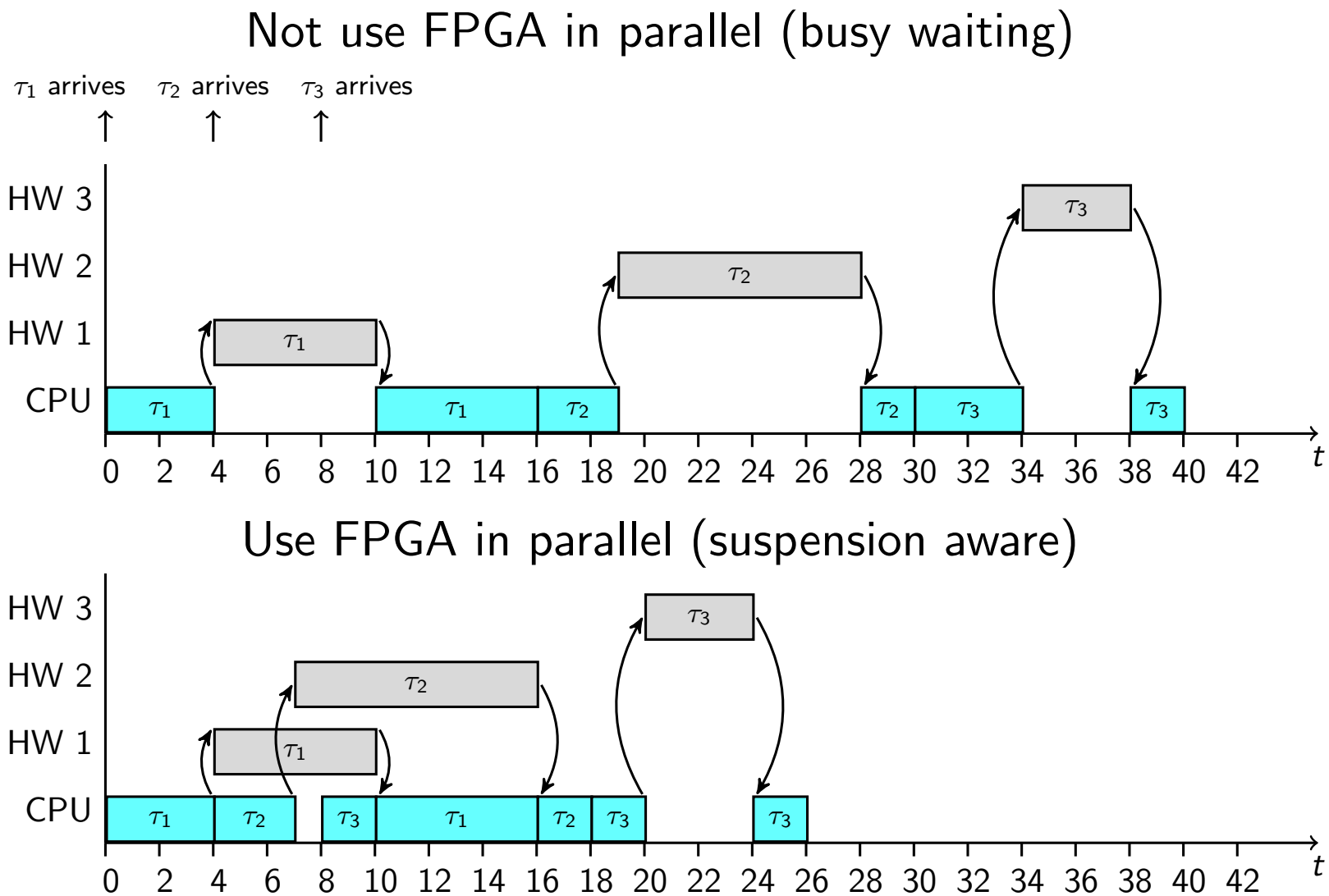
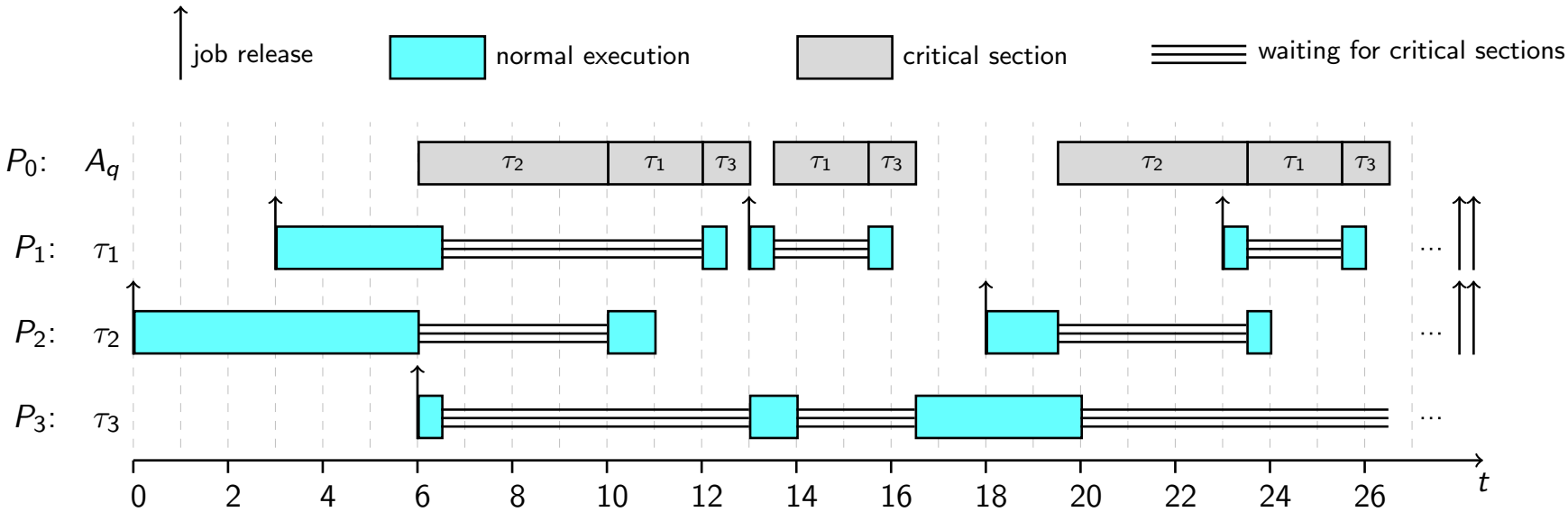
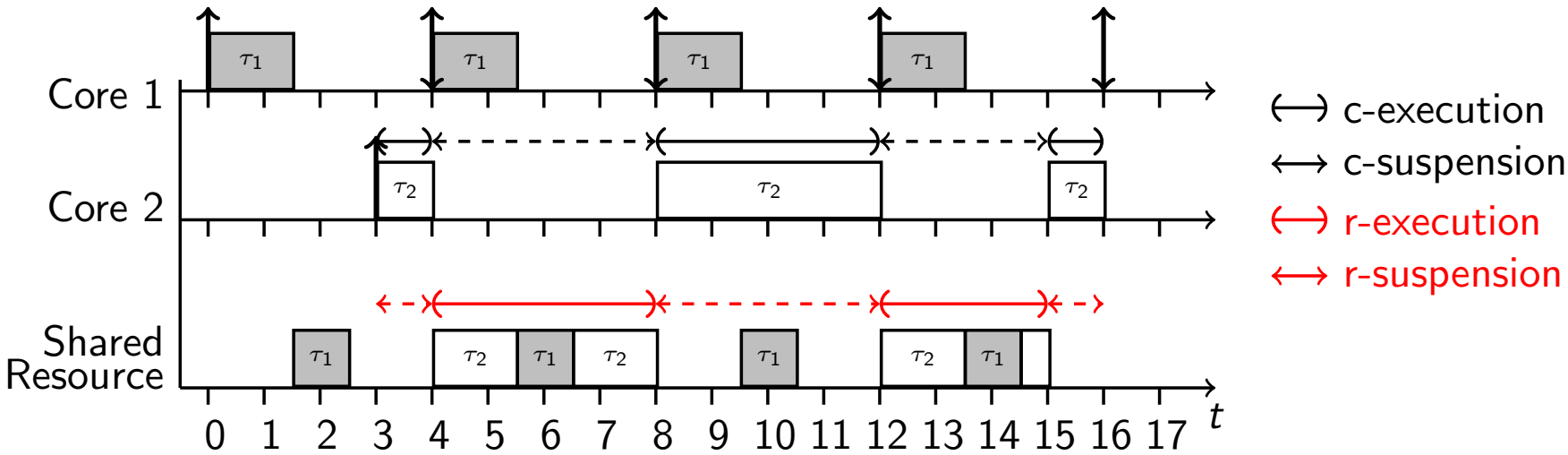


Reasons for Self-Suspension: Locking Protocols



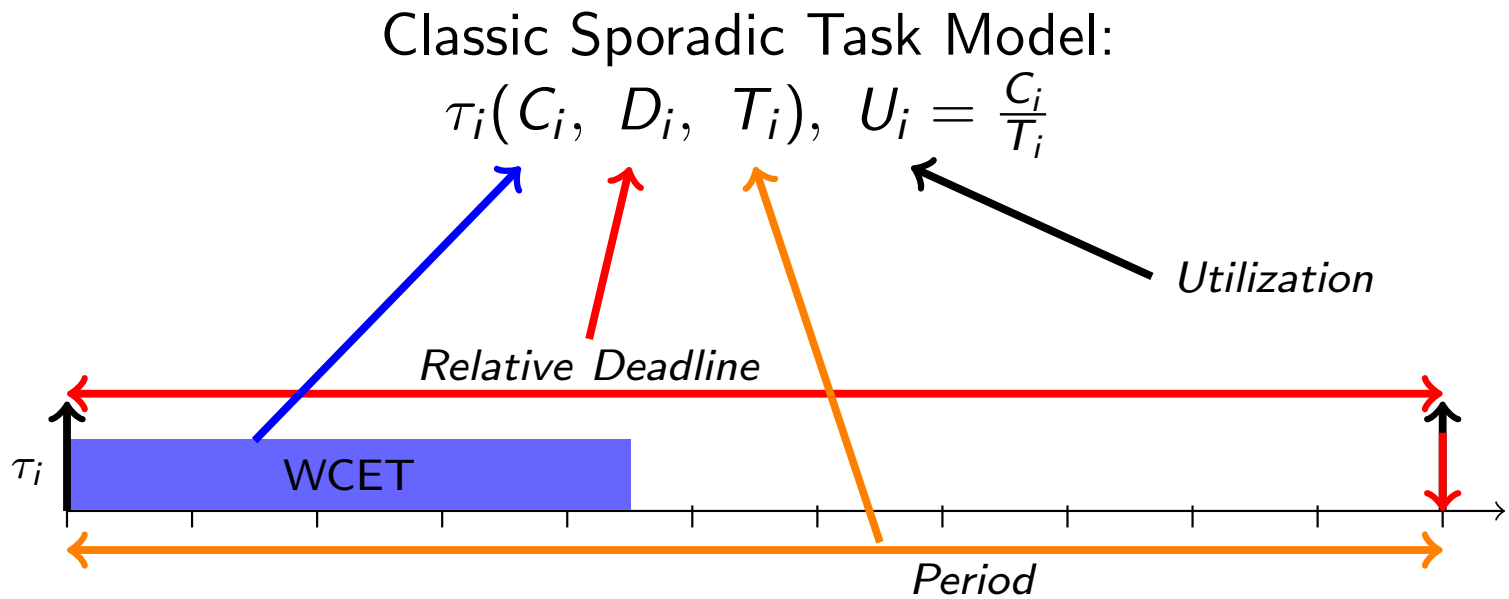
- Semaphores in multiprocessor systems: remote blocking due to mutual exclusion

Reasons for Self-Suspension: Physical Resource Sharing



- Multiple cores may share a bus
- Memory centric scheduling

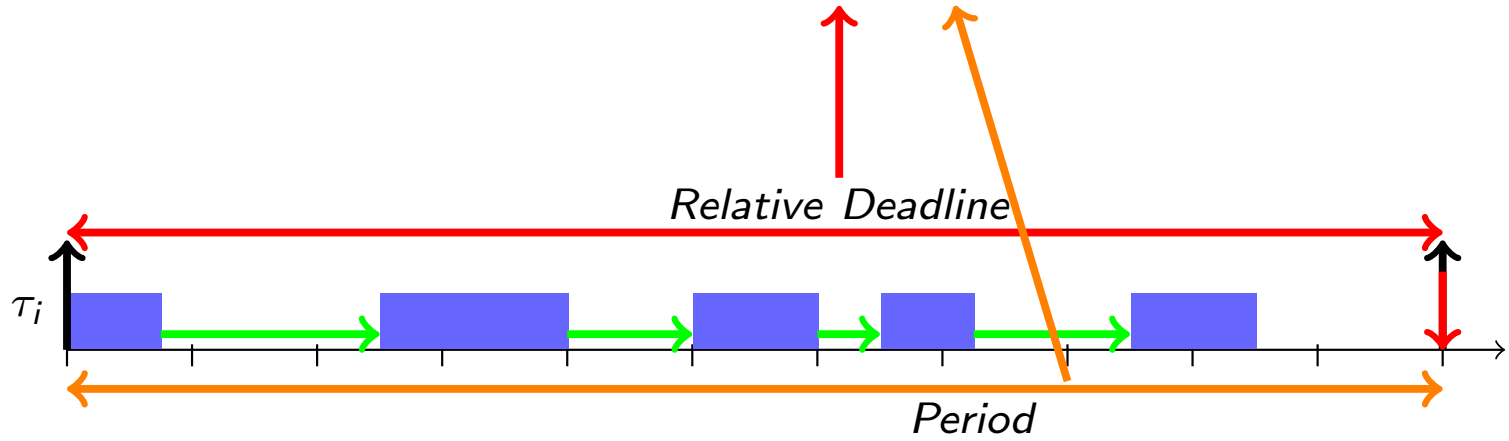
Self-Suspension Task Models



Self-Suspension Task Models

Dynamic Self-Suspending Sporadic Task Model:

$\tau_i((C_i, S_i),\ D_i,\ T_i)$

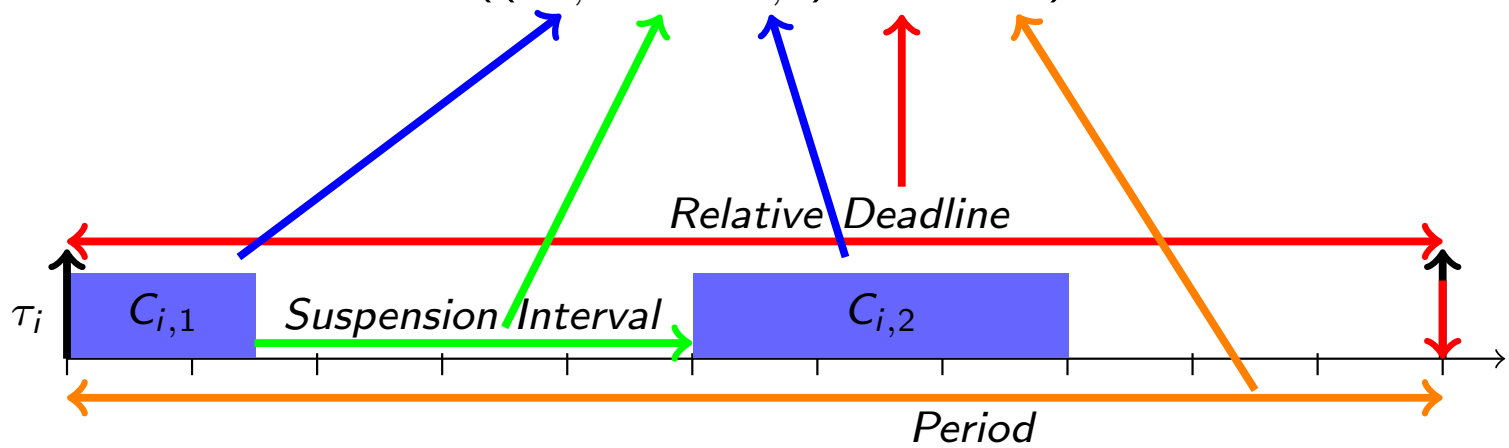


- S_i = maximum total suspension time
- C_i = sum of segment WCETs
- No information about the execution / suspension pattern
- Flexible and inaccurate

Self-Suspension Task Models

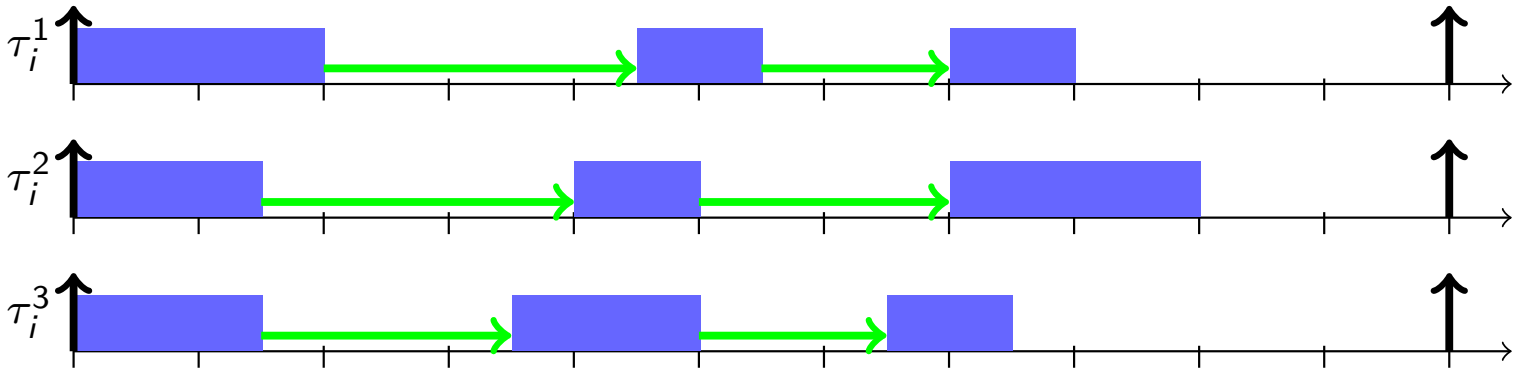
Segmented Self-Suspending Sporadic Task Model:

$\tau_i((C_{i,1}, S_i, C_{i,2}),\ D_i,\ T_i)$



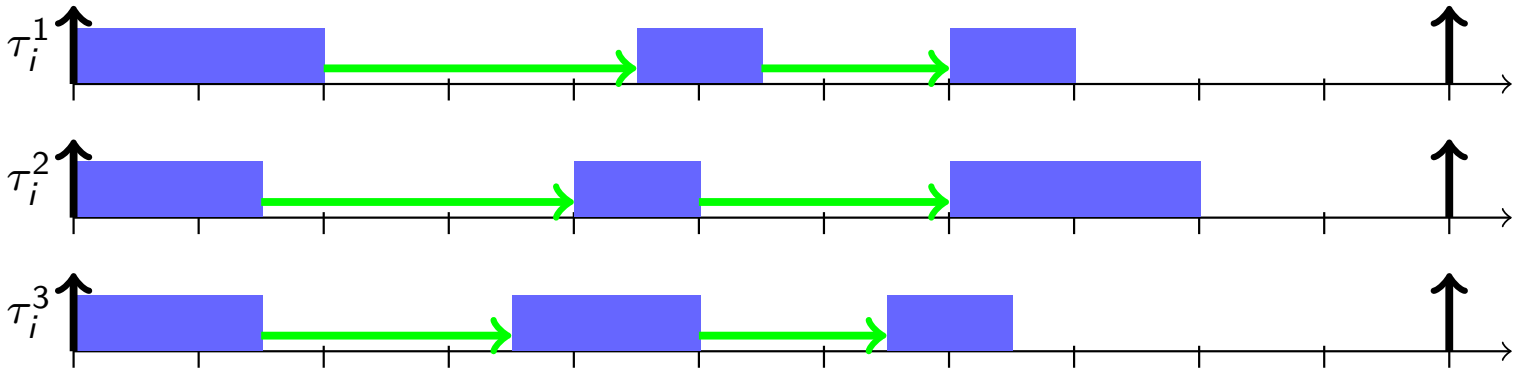
- Fixed interleaved execution / suspension pattern
- Accurate and restrictive

Hybrid Self-Suspension Models



- Set of execution / suspension patterns

Hybrid Self-Suspension Models



- Set of execution / suspension patterns
- Assumes number of suspension intervals to be given

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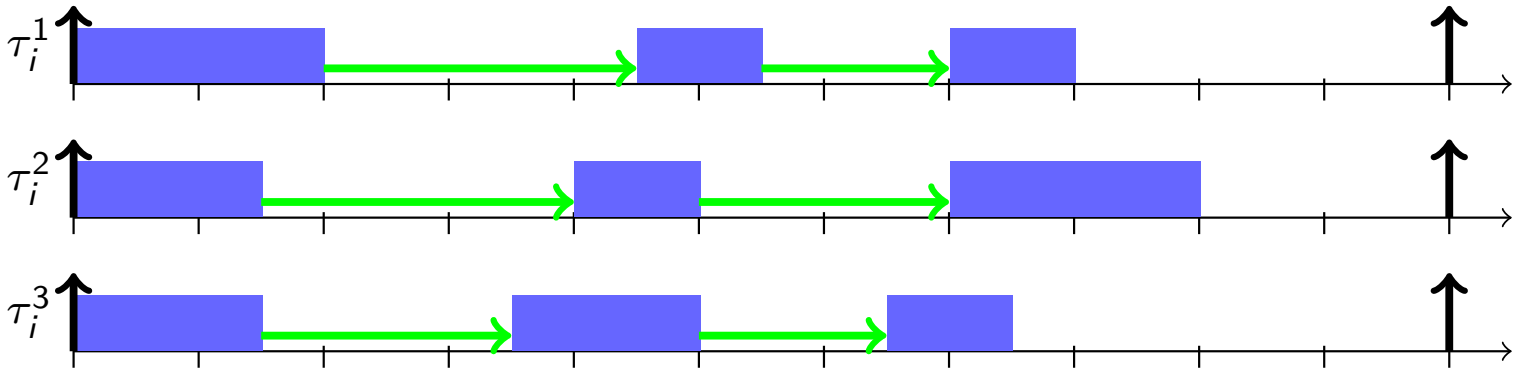

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- Assumes number of suspension intervals to be given
- Different tradeoffs regarding flexibility and accuracy

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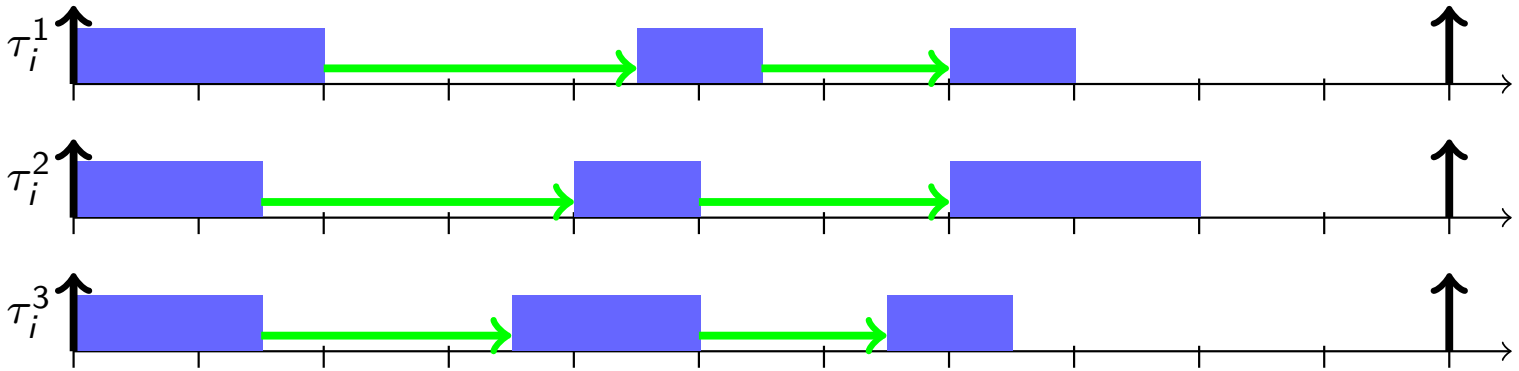

- Set of execution / suspension patterns
- Assumes number of suspension intervals to be given
- Different tradeoffs regarding flexibility and accuracy
- Depending on
  - Additional information
  - Time information is available

A Brief Overview

- Self-suspension models with different application scenarios
- Scheduling algorithms and schedulability tests

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- Here: fundamental theoretical analysis of the most basic recurrent setting, i.e., frame based tasks

Results from Operations Research - Uniprocessor

- Kern and Nawijn 1991: multi-operation jobs with time lags

Multi-Operation Jobs with Time Lags on a Single Machine

There are jobs to be processed on a single machine. Each job requires two operations to be processed in a given order. The time between the start of the second operation and the completion of the first operation cannot be less than a pre-specified time constant, i.e., there is a minimal time lag between the two operations of a job. Our aim is to minimize the makespan, i.e., the completion time of the second operation of the last job in the schedule.

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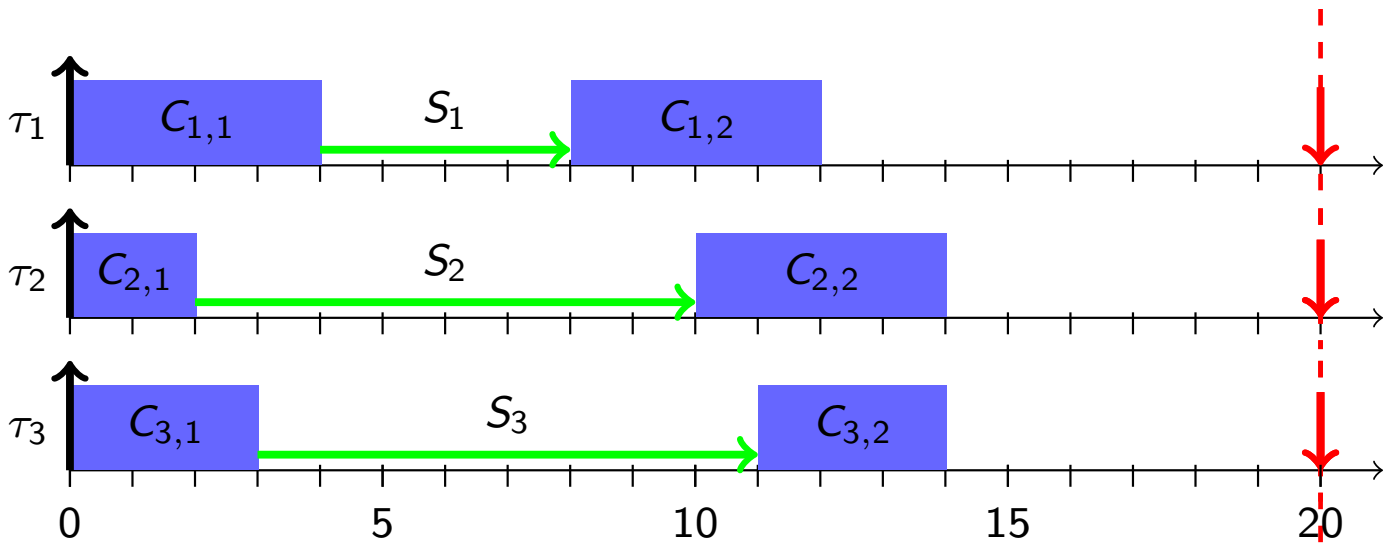
- Identical to frame-based one-segmented self-suspension



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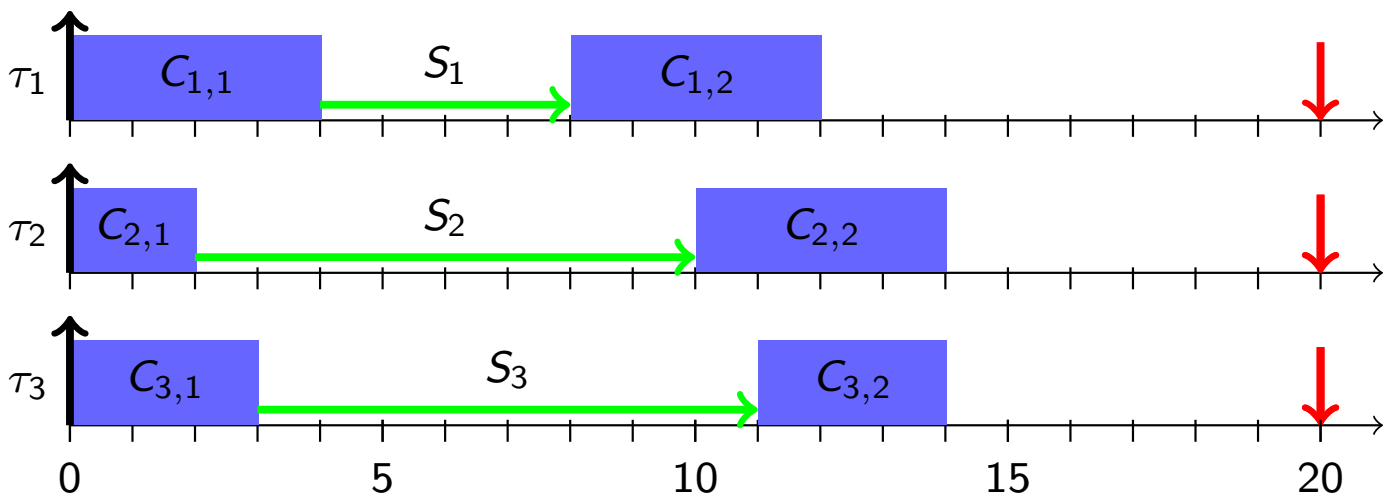

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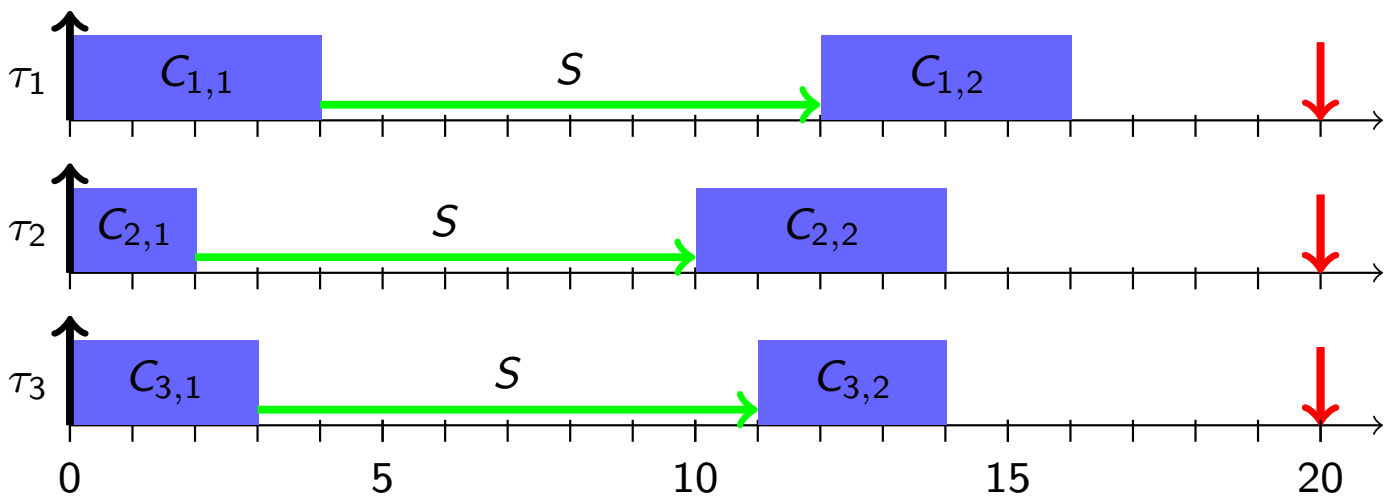

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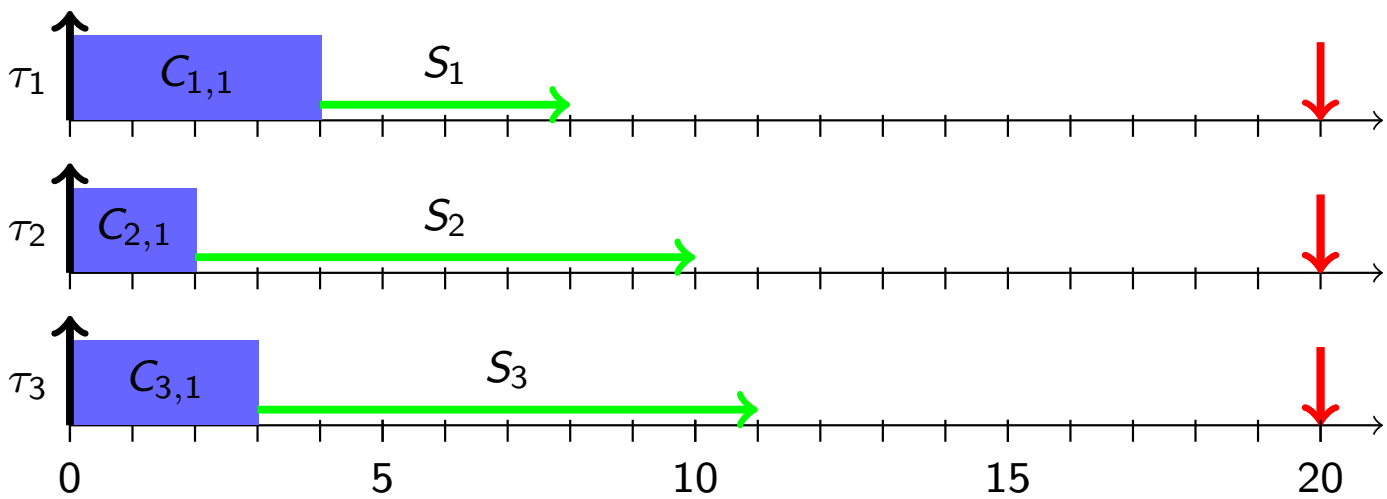
  - All jobs have only the first operation $\Rightarrow$ $C_{i,2} = 0$



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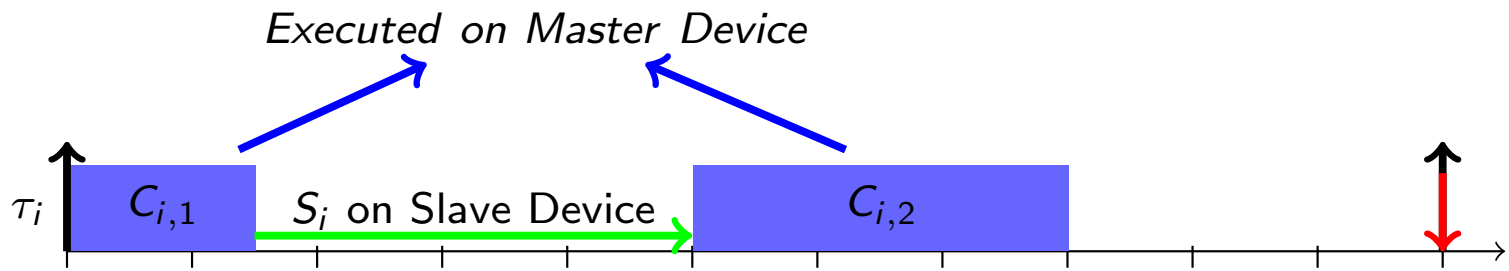
- Sahni 1995: master-slave scheduling model



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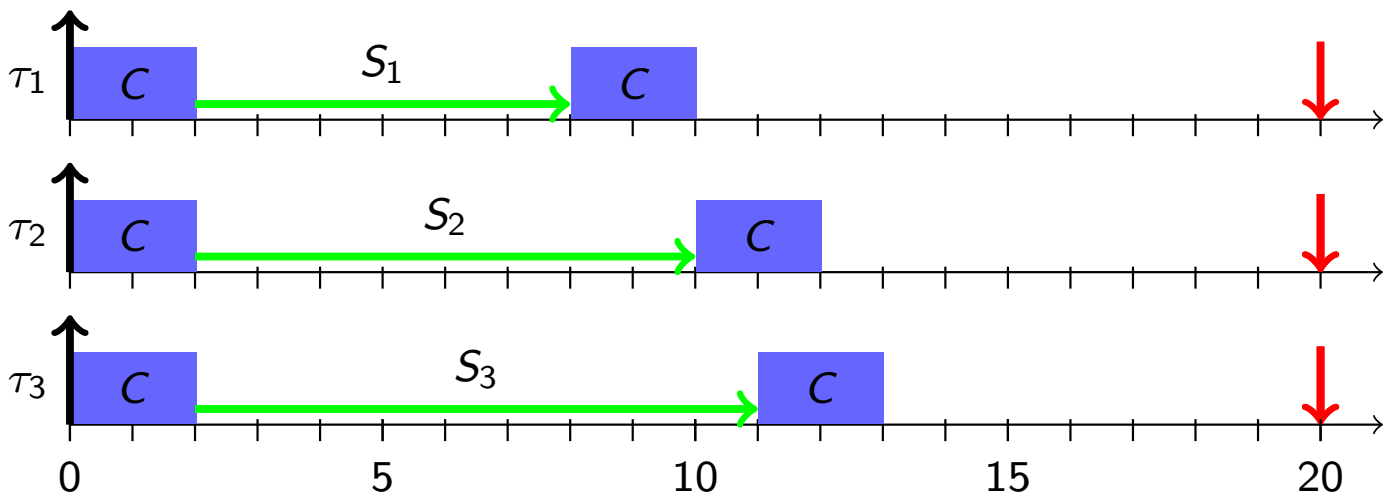

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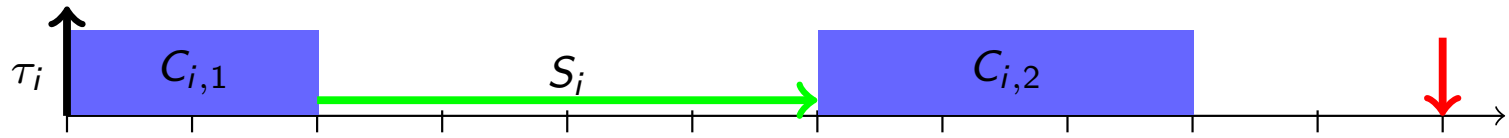
Conclusion

The computational complexity of the scheduler design problem of segmented self-suspension task systems is mainly due to the non-uniform *self-suspension time*.
Removing the periodicity and non-uniform execution times of the computation segments does not make the problem easier with respect to the computational complexity.

Speedup Factors - Coherent and Only Processor



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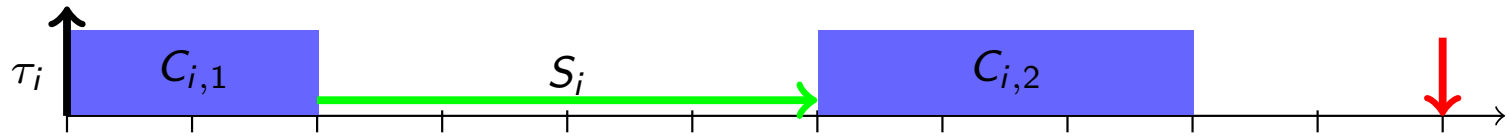
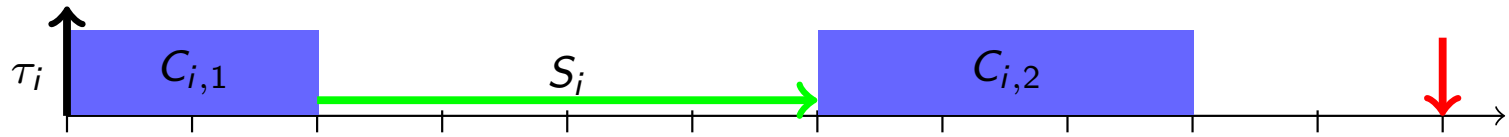


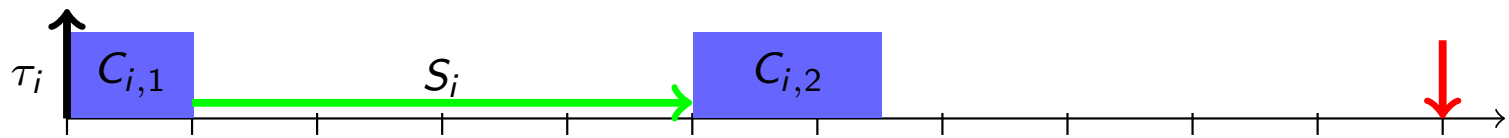
Suspension-coherent speedup (by 2)

Speedup Factors - Coherent and Only Processor



Suspension-coherent speedup (by 2)

Speedup only the processor (by 2)



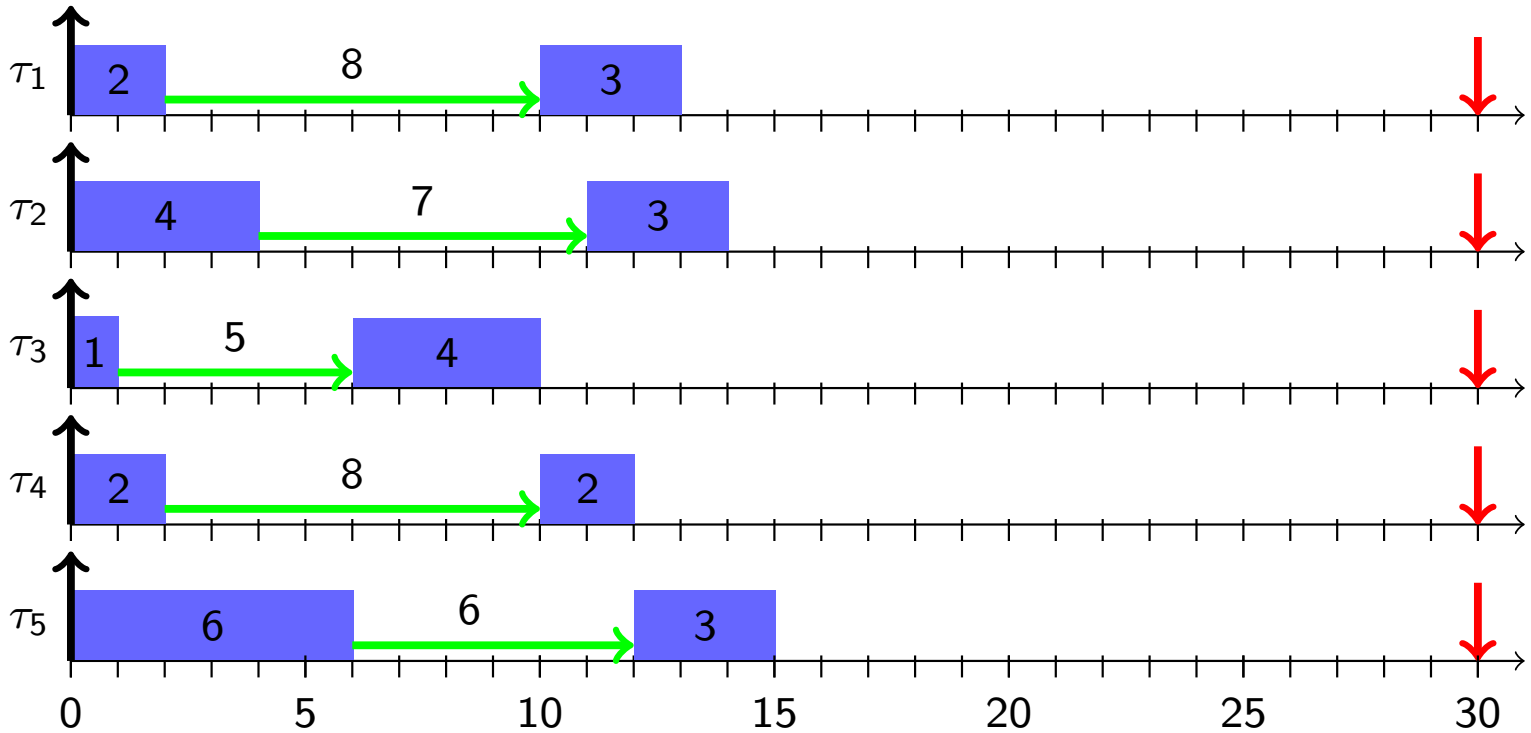
Speedup Factors - Current Status

Uniprocessor	segmented (one suspe.)	hybrid (one suspe.)	dynamic (multiple suspe.)
coherent	1.5 [42]	-	-
only processor	-	-	-

Multiprocessor *m* identical	segmented (one suspe.)	hybrid (one suspe.)	dynamic (multiple suspe.)
coherent	2 [42]	2 [42]	-
only processors	-	-	-

[42] Sahni and Vairaktarakis 1996

Algorithm by Sahni and Vairaktarakis



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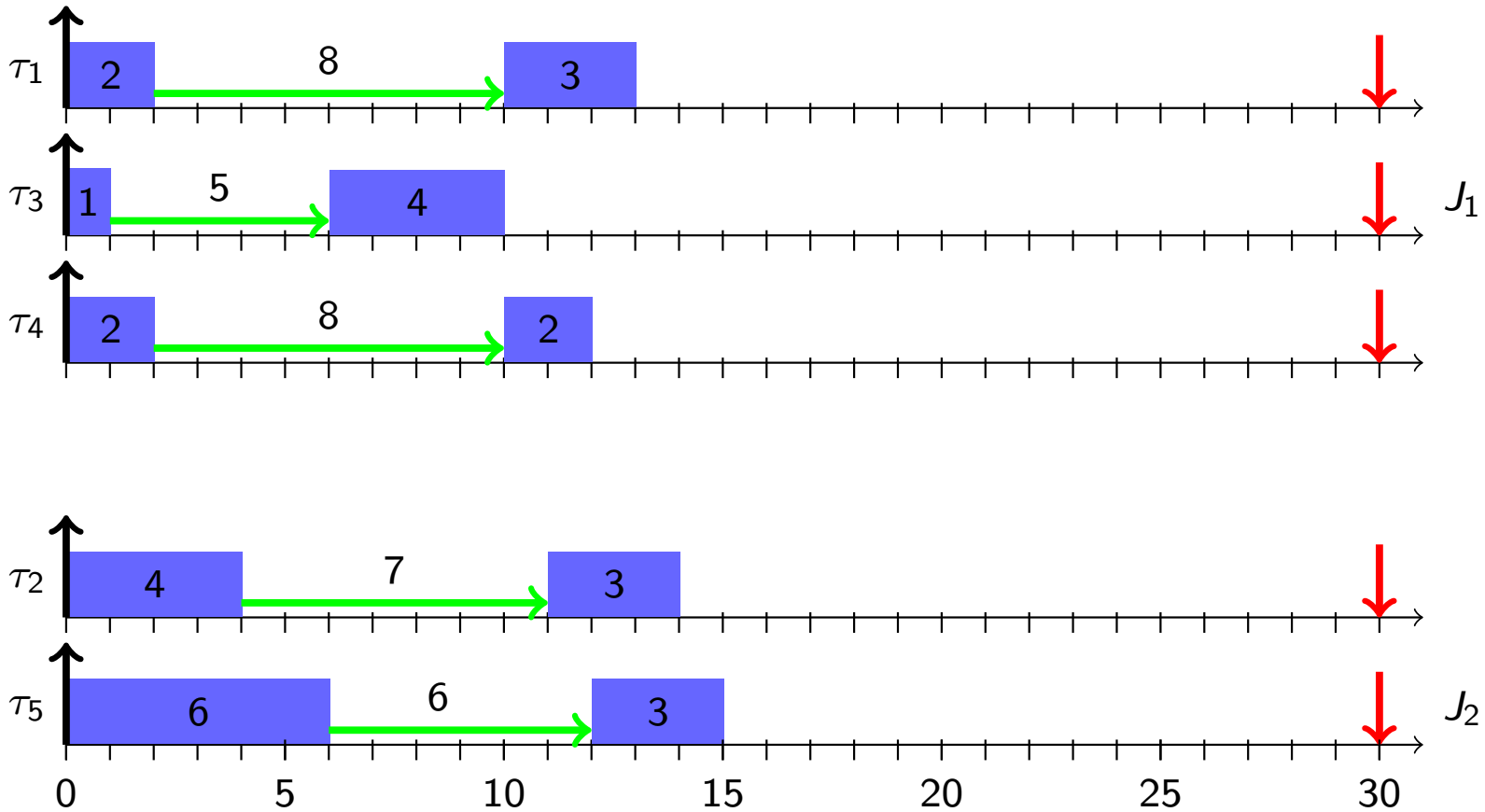
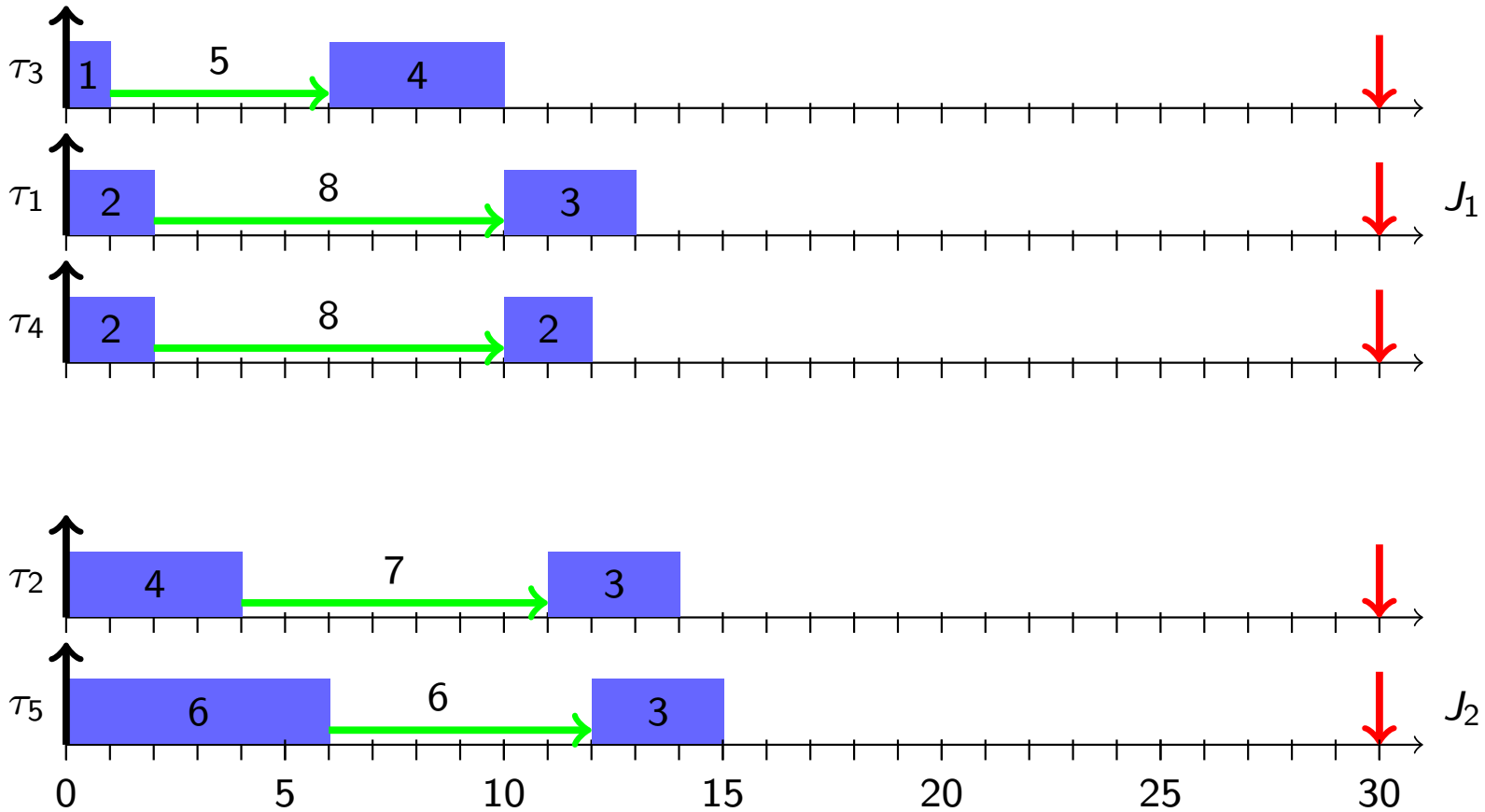


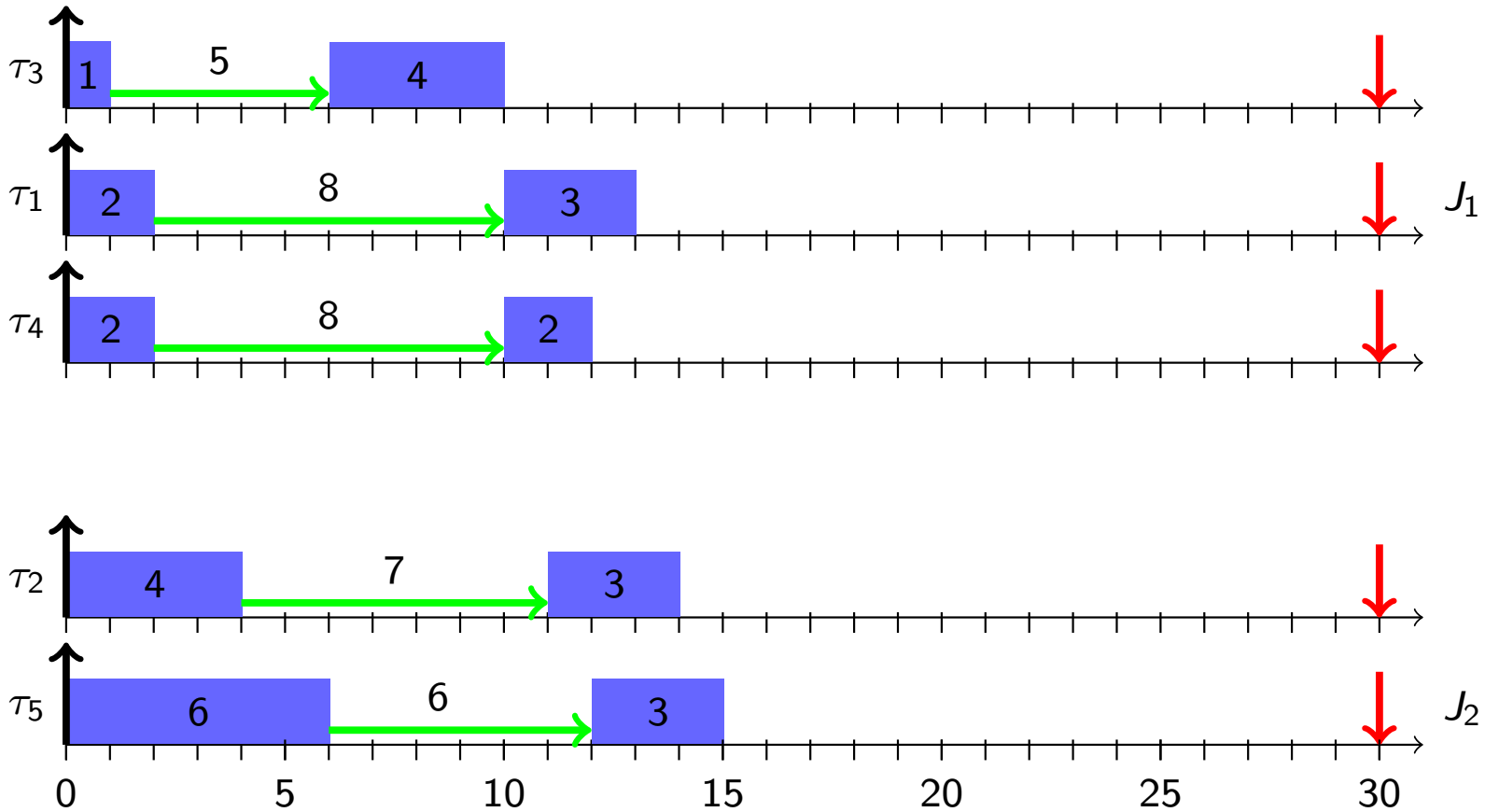
$J_1 : \ C_{i,1} \leq C_{i,2} \qquad J_2 : \ C_{i,1} > C_{i,2}$

Algorithm by Sahni and Vairaktarakis



J_1: order non-decreasing to S_i - shortest suspension first

Algorithm by Sahni and Vairaktarakis



J_2: order non-increasing to S_i - longest suspension first

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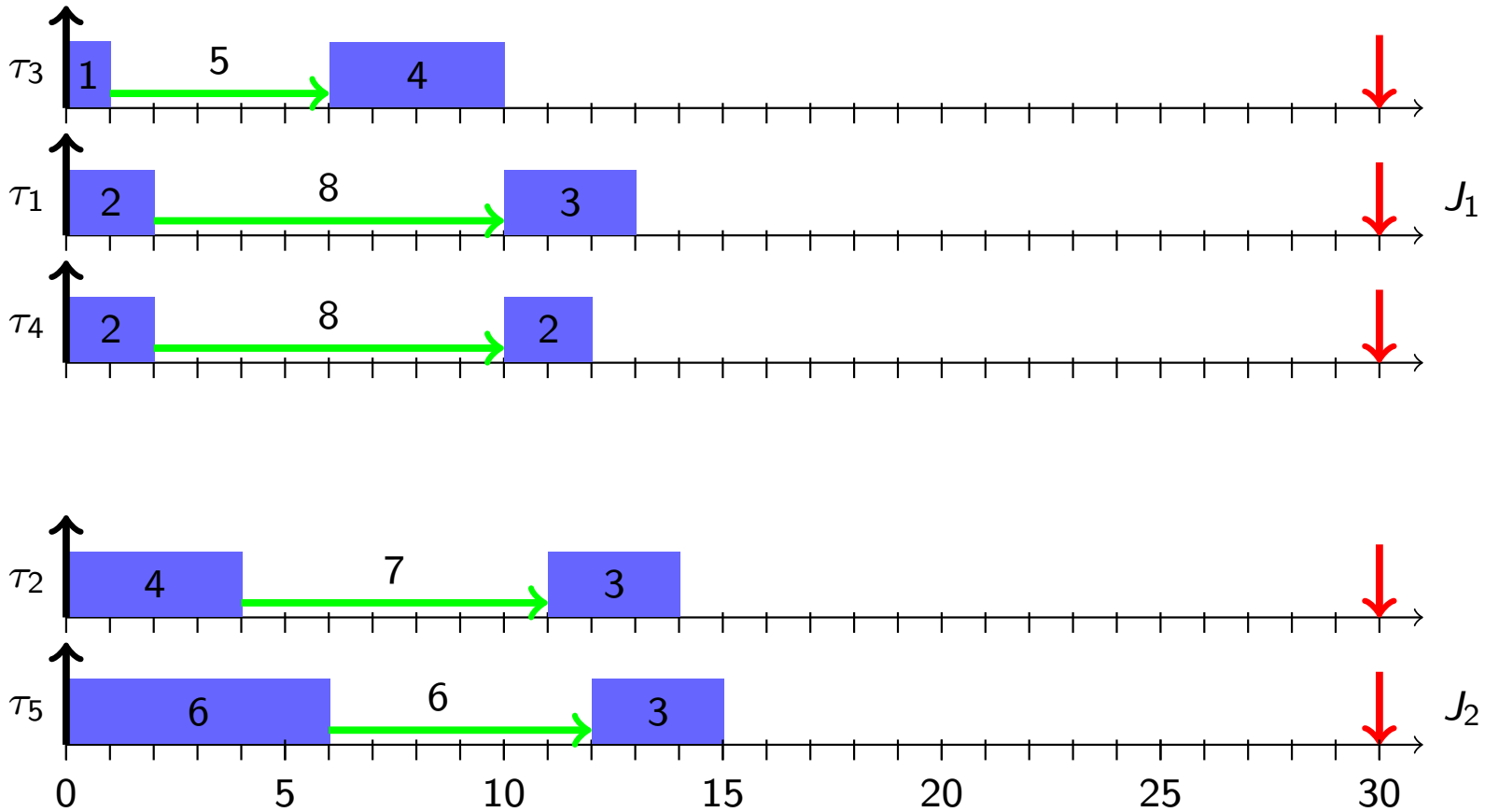
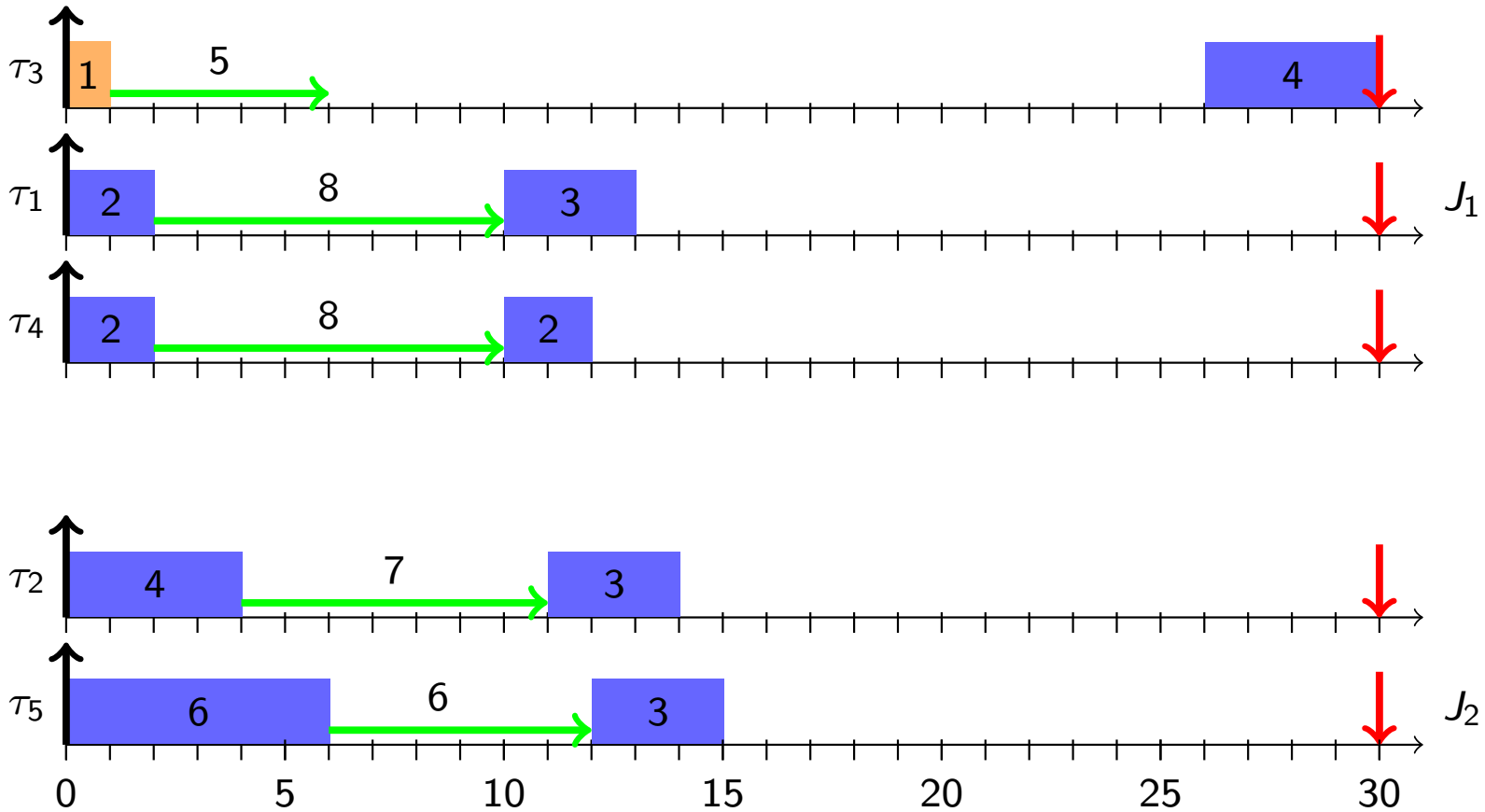


Schedule J_1, then J_2 according to order

Prioritize first computation segments

Algorithm by Sahni and Vairaktarakis



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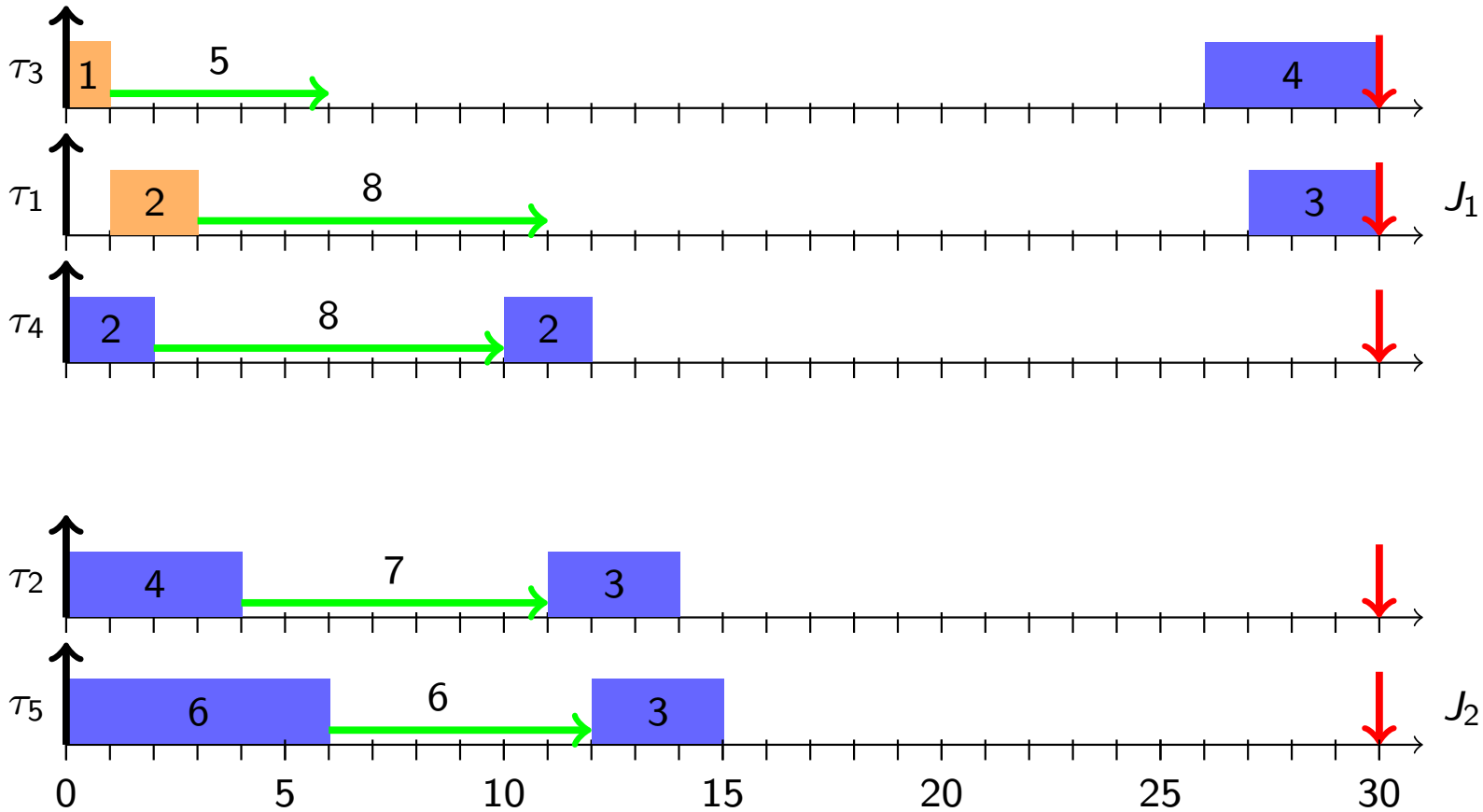

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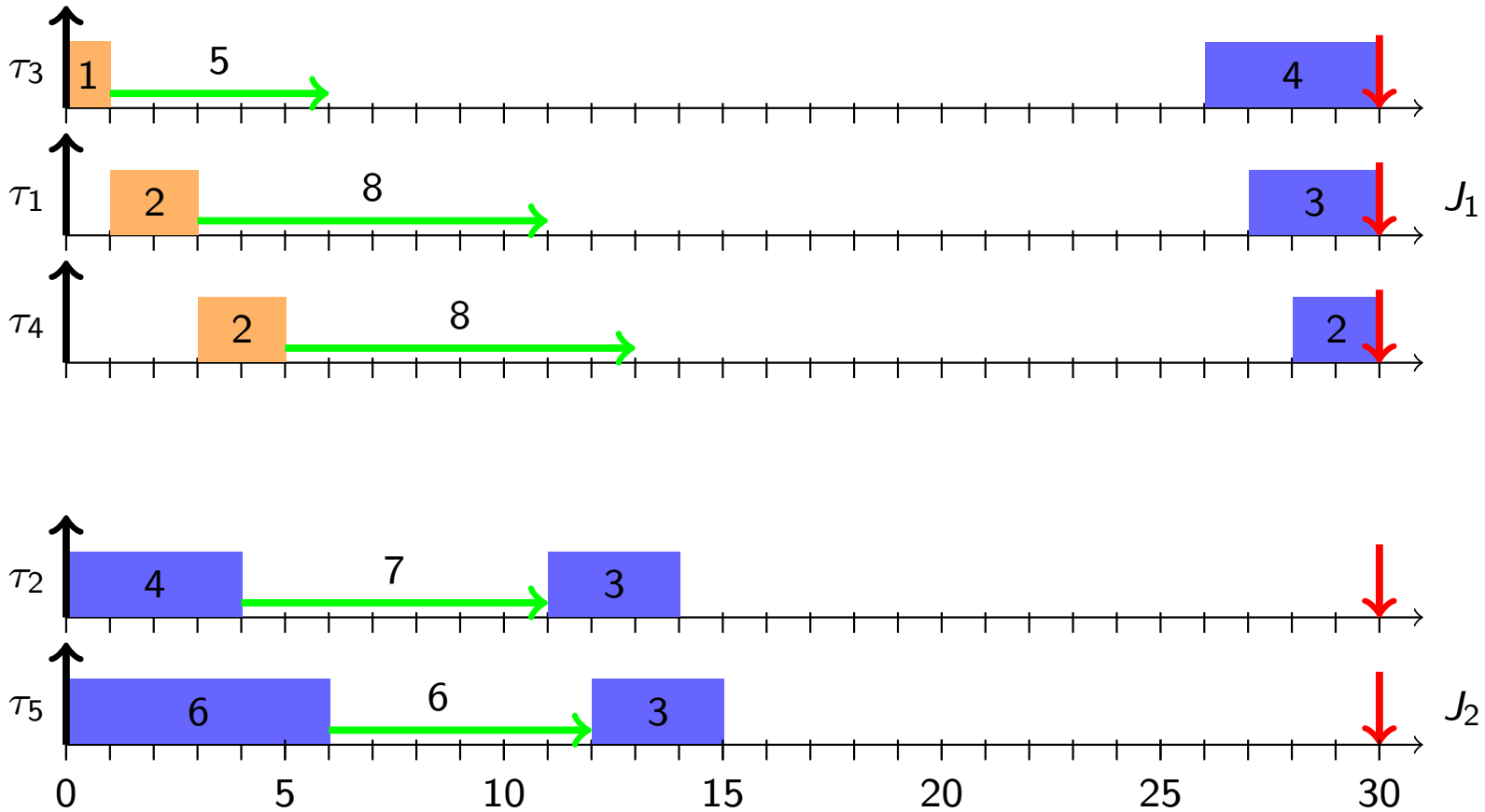

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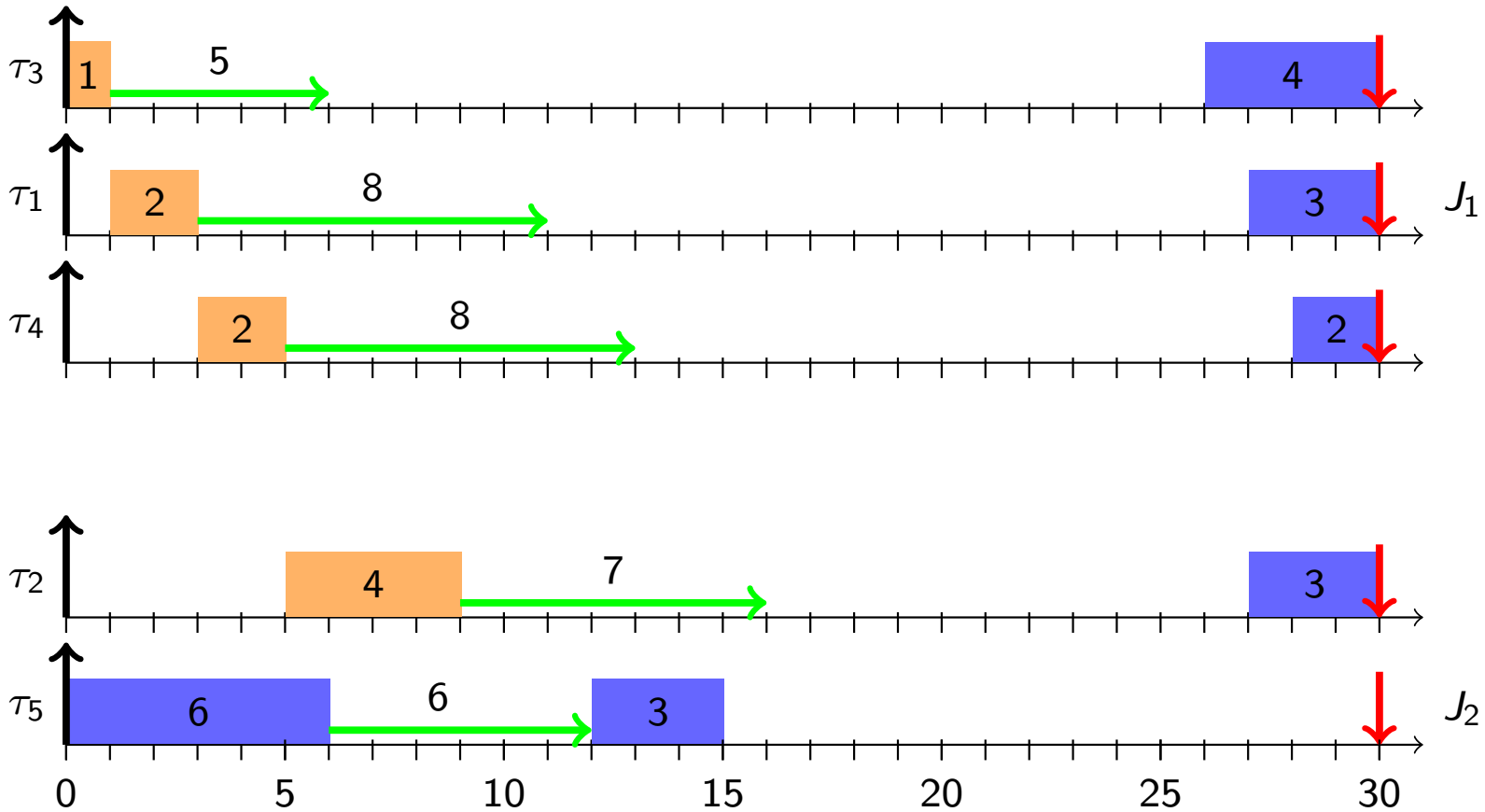

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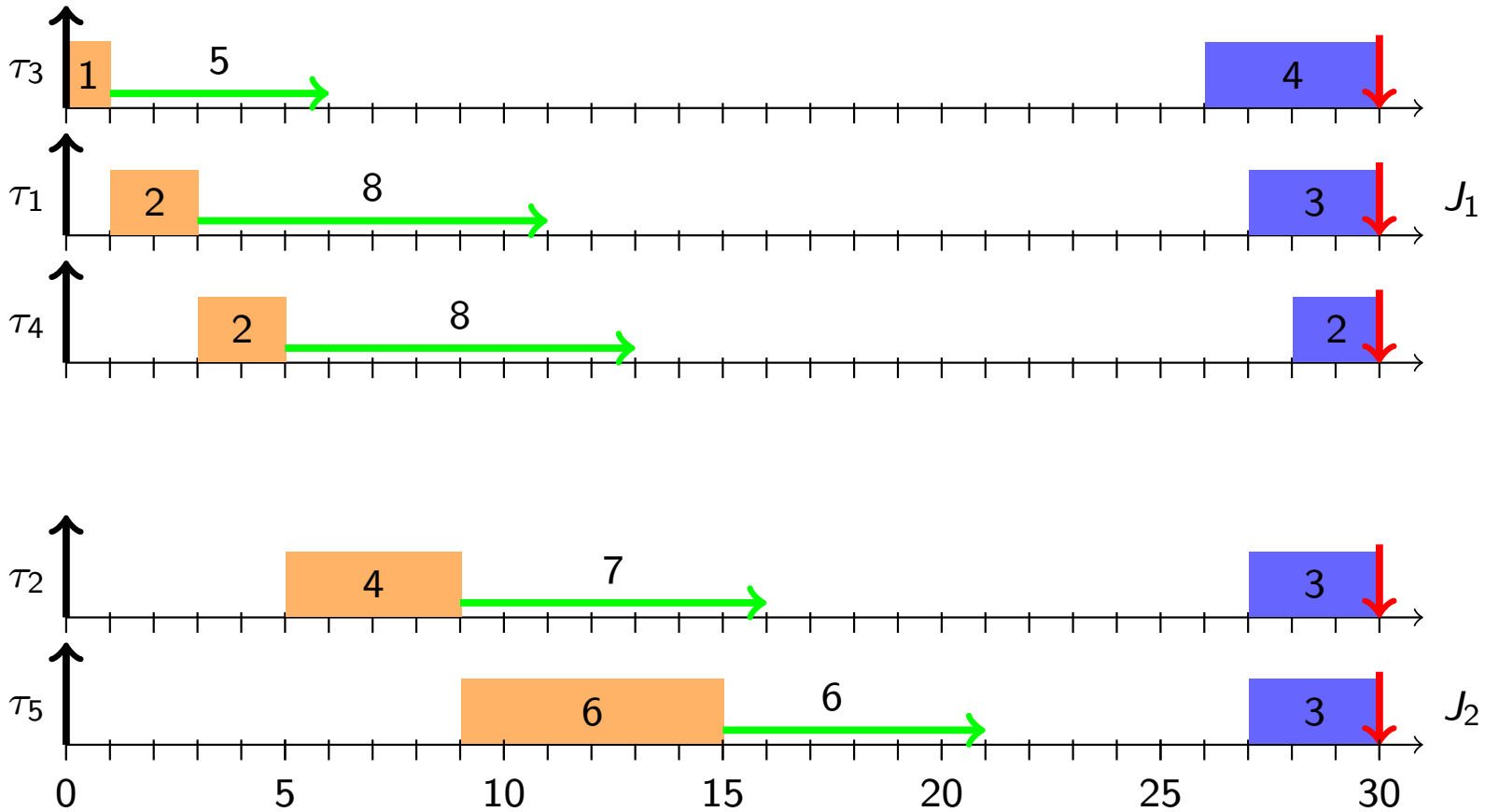
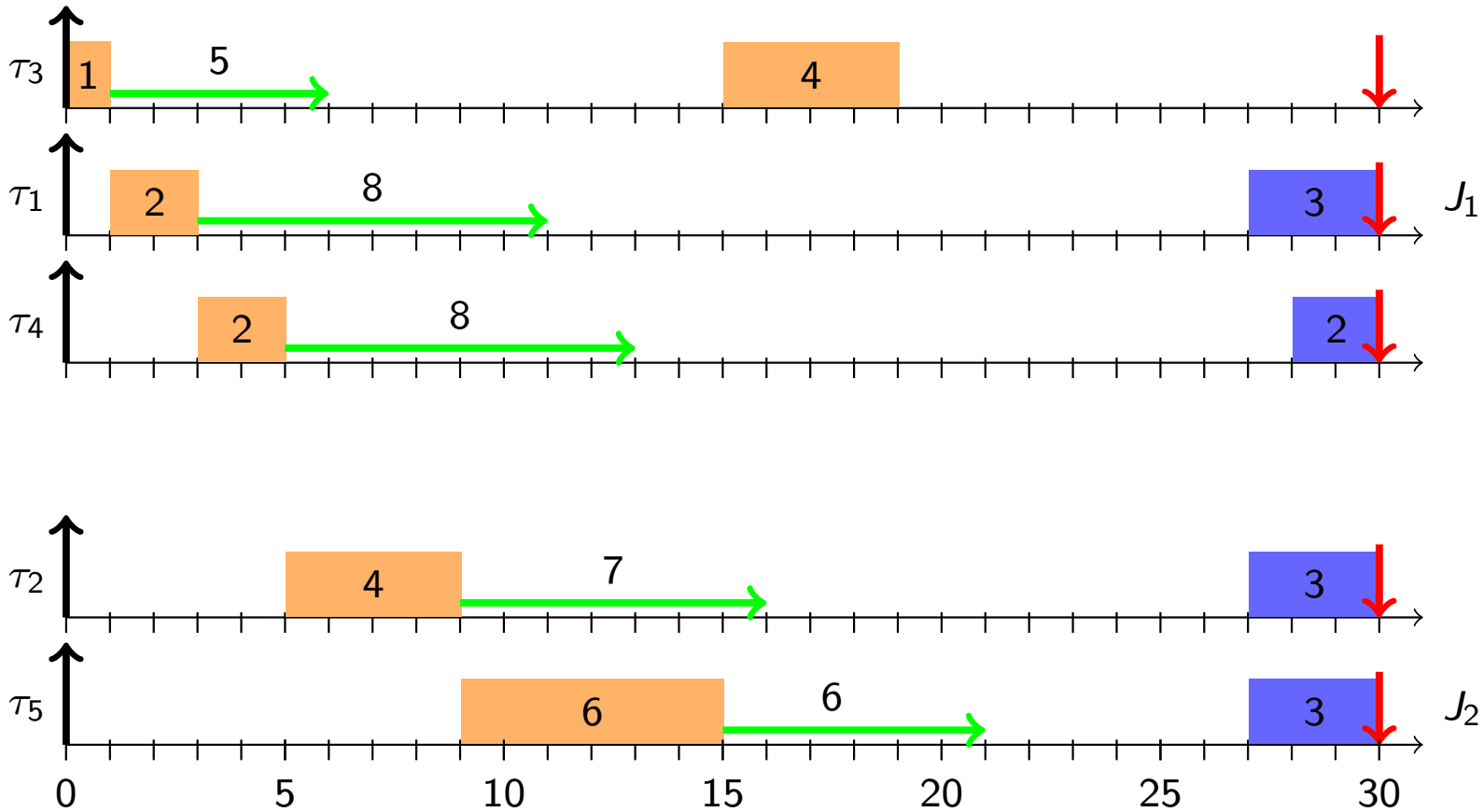


Schedule J_1, then J_2 according to order

Prioritize first computation segments

Algorithm by Sahni and Vairaktarakis



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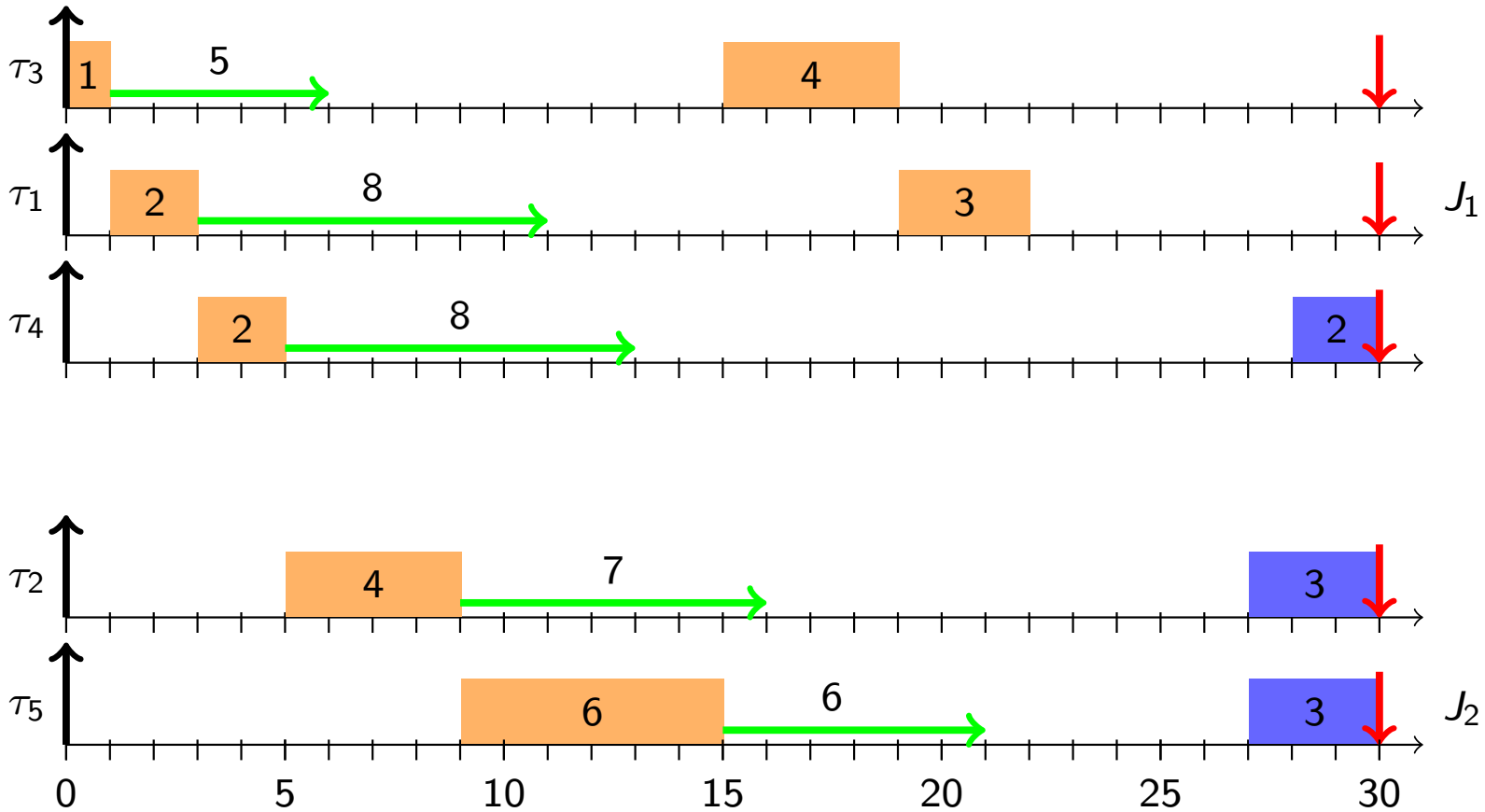

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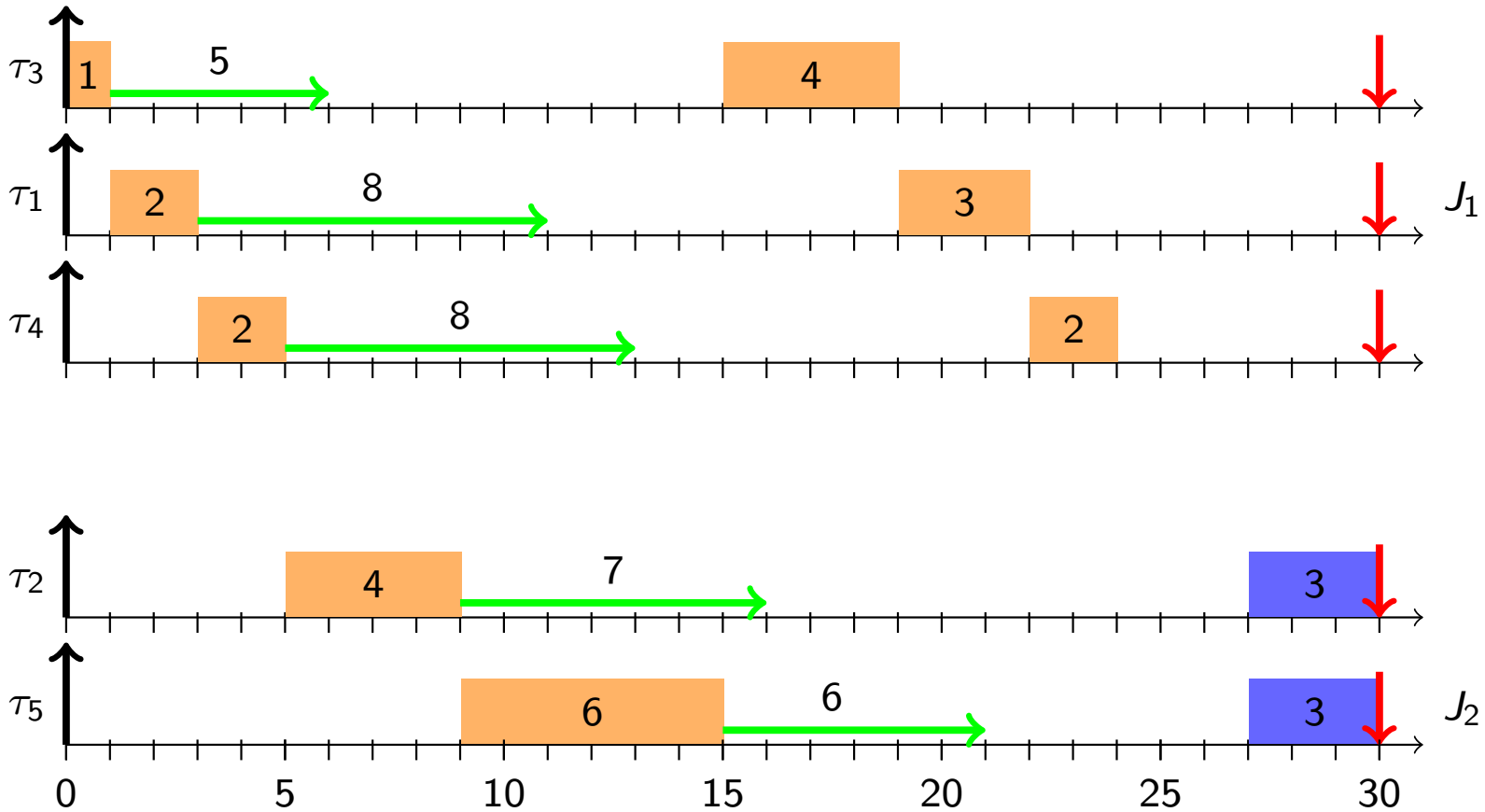

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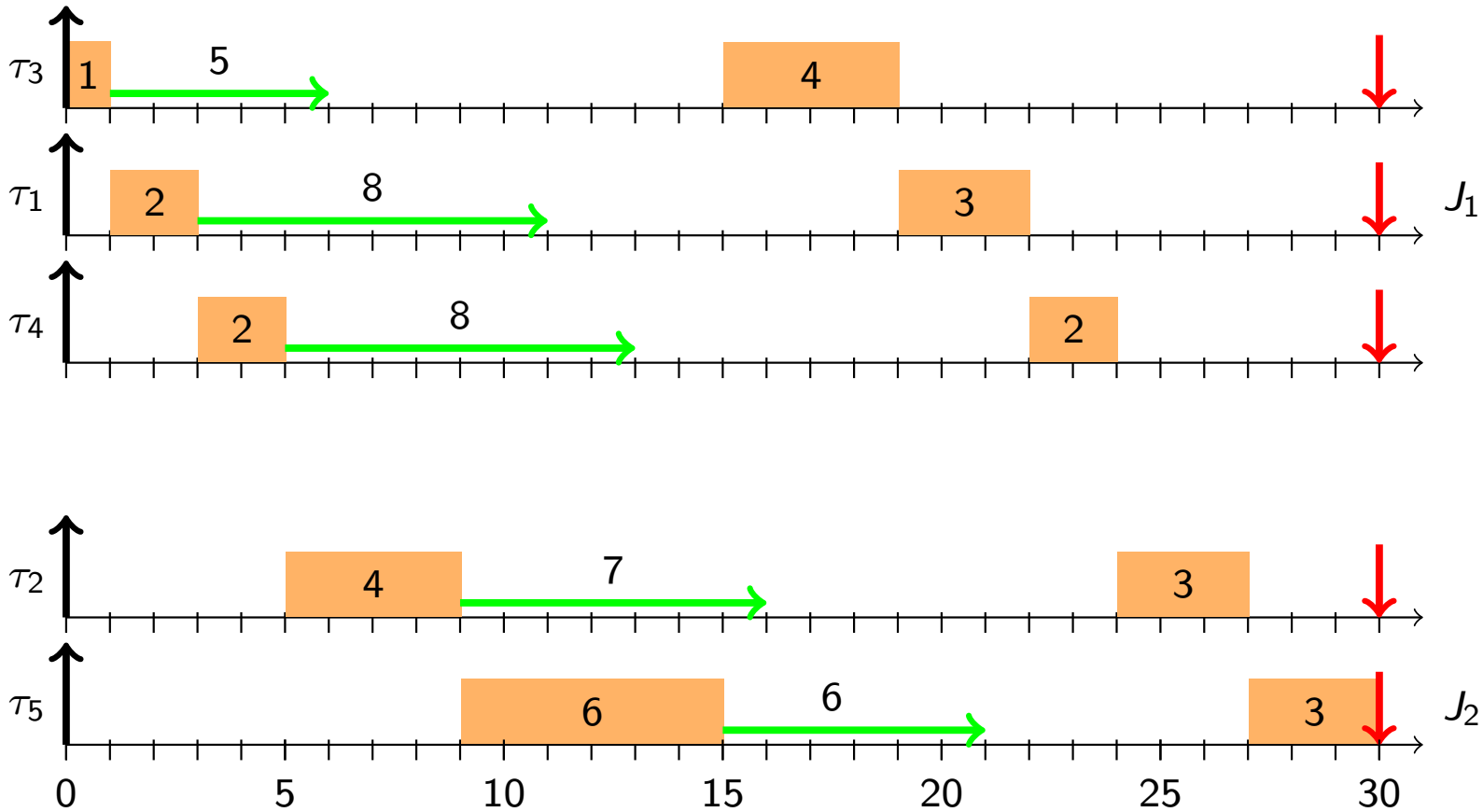

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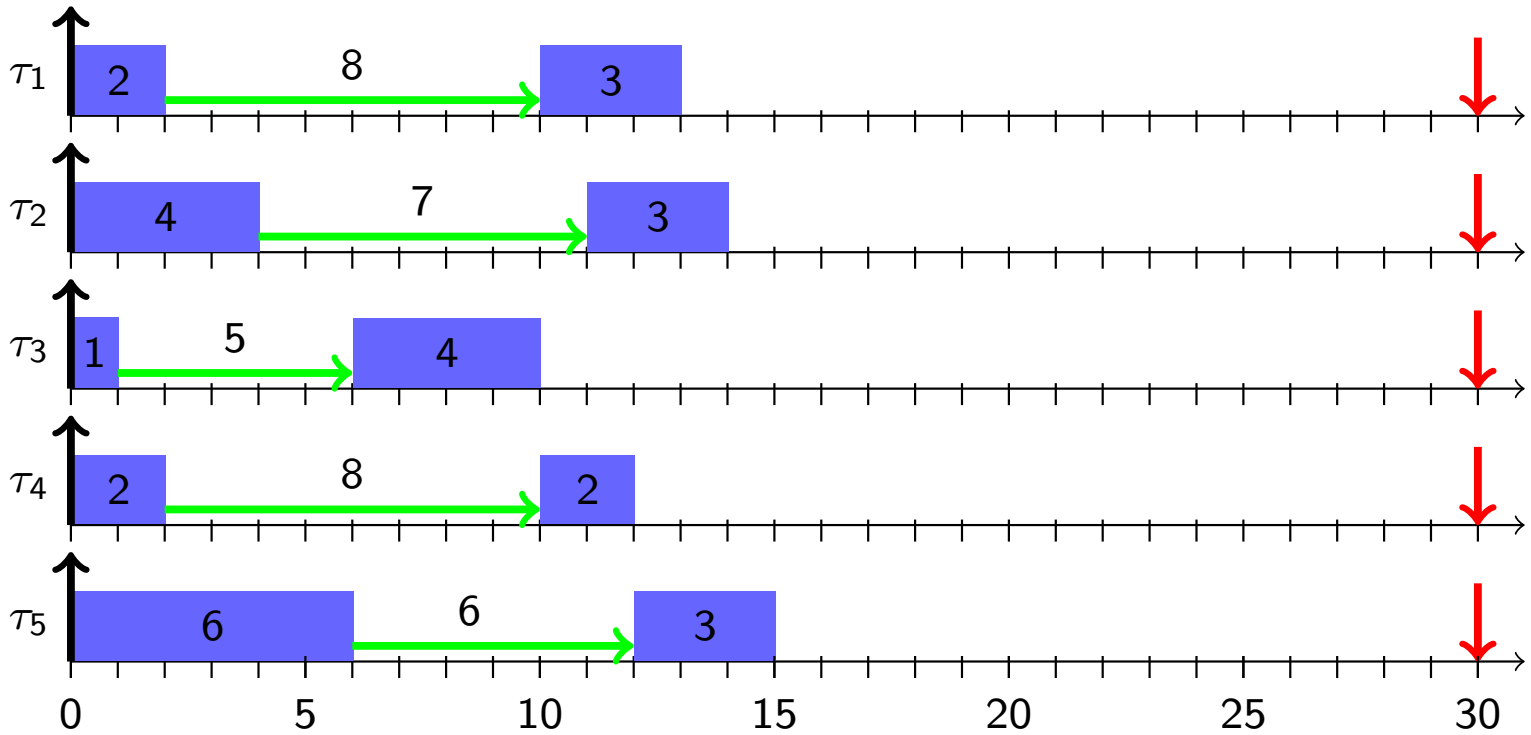
Prioritize first computation segments

Longest Suspension First Algorithm



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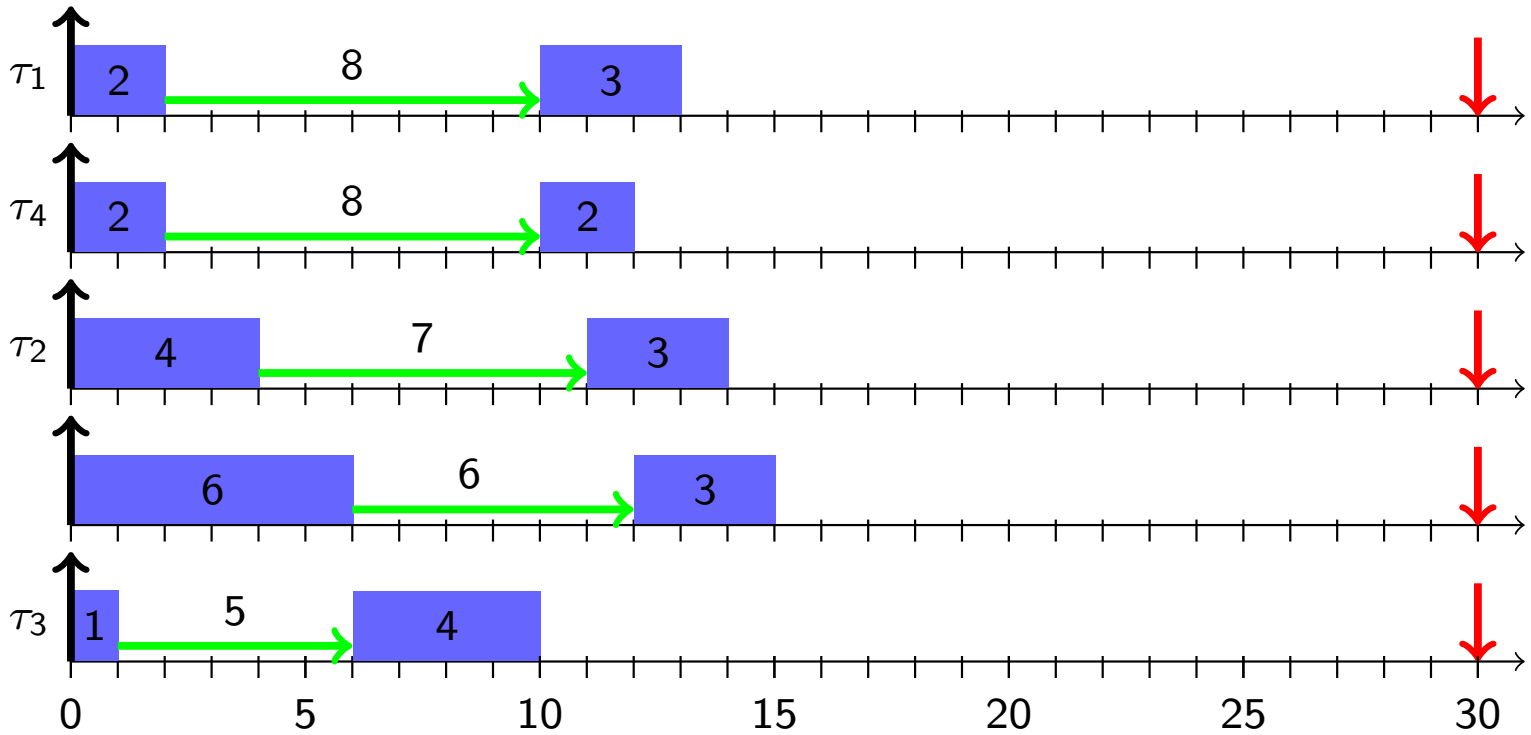
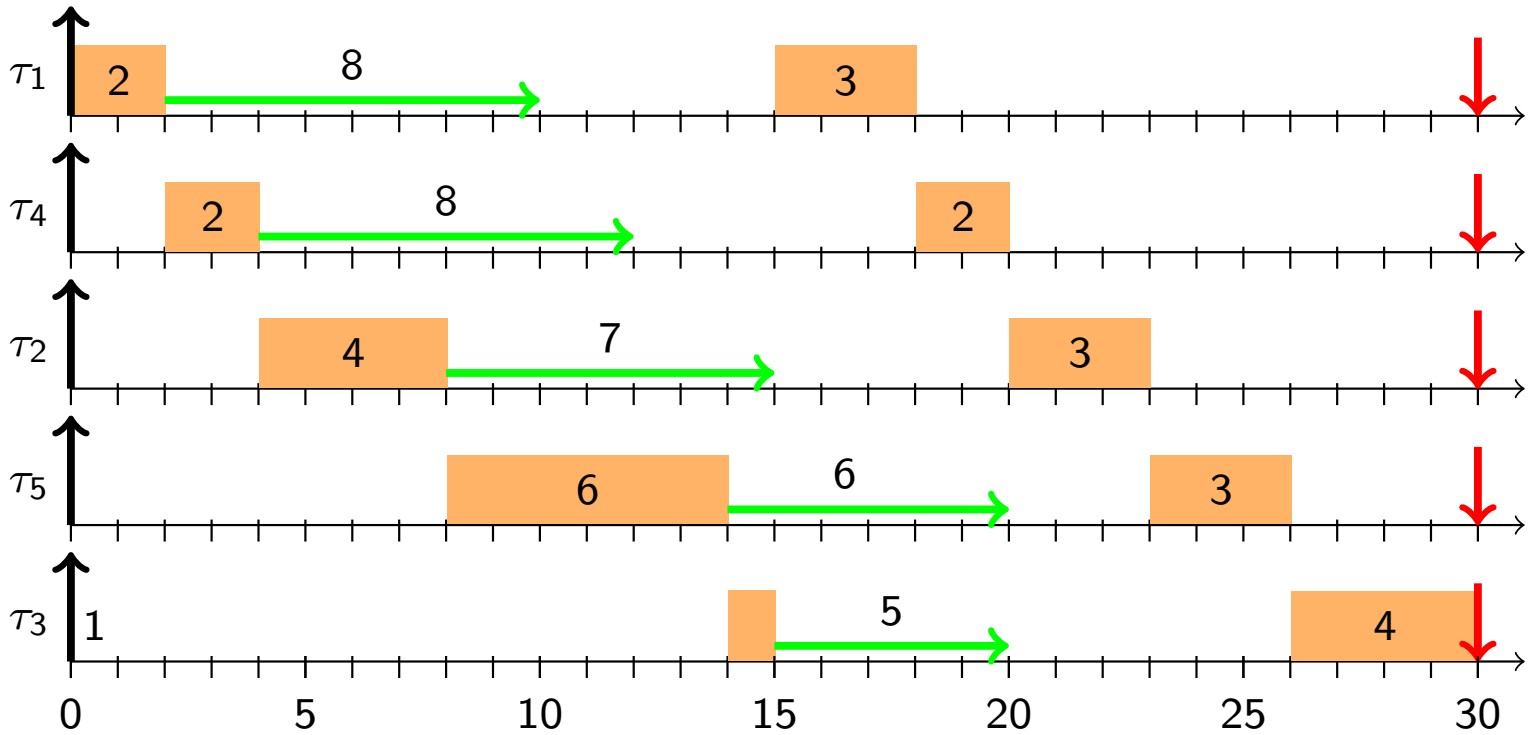


Order non-increasingly according to S_i

Longest Suspension First Algorithm



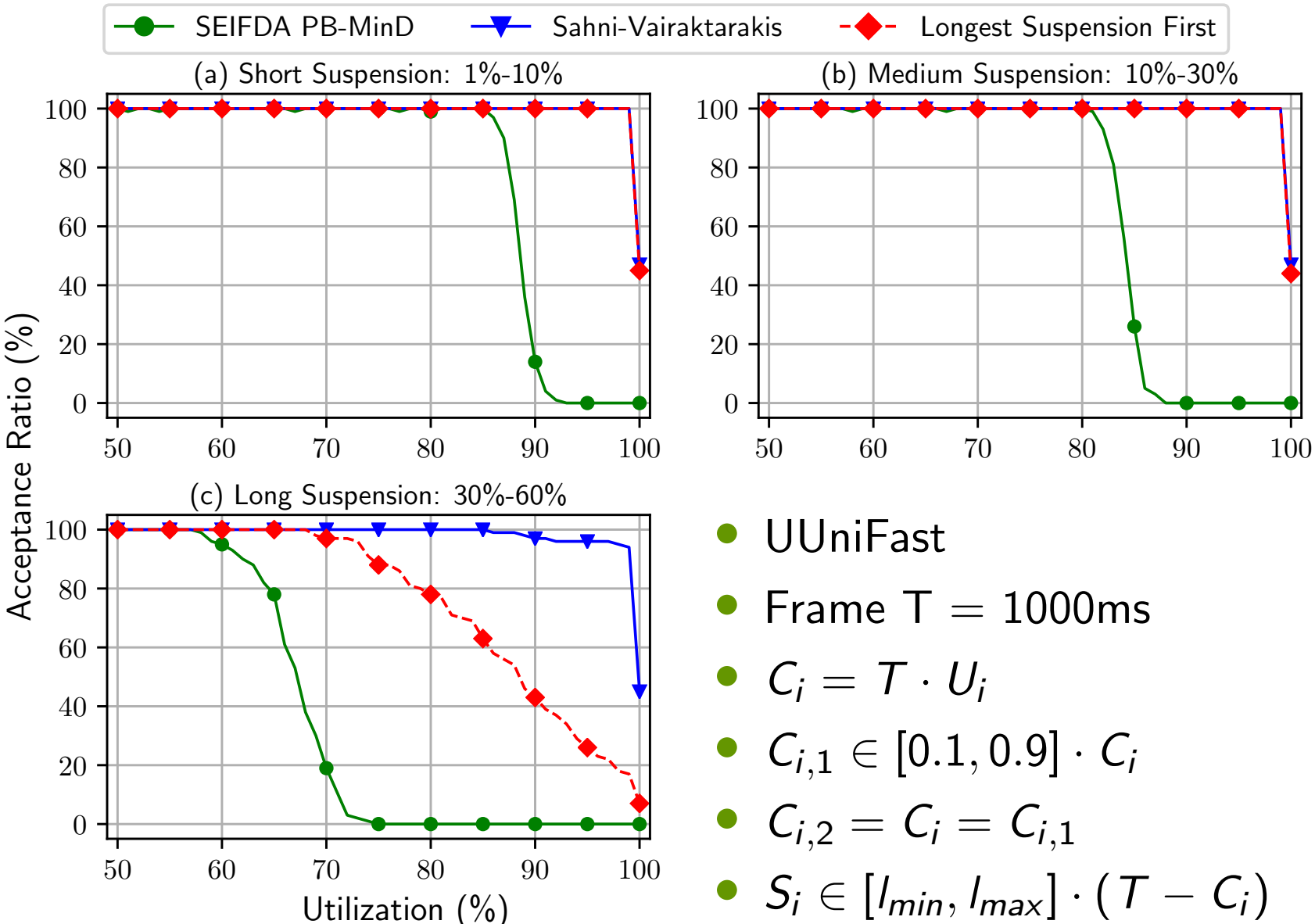
Schedule first computation segments according to order
Schedule second computation segments according to FCFS

Speedup Factors - New Results

Uniprocessor	segmented (one suspe.)	hybrid (one suspe.)	dynamic (multi sus.)
coherent	1.5 [42]	1.5 (Cor. 4.5)	2 (Thm. 4.7)
only processor	2 (Thm. 4.12)	2 (Thm. 4.13)	-
Multiprocessor m identical	segmented (one suspe.)	hybrid (one suspe.)	dynamic (multi sus.)
coherent	2 [42]	2 [42]	2 (Thm. 5.5)
only processors	$3 - \frac{1}{m}$ (T. 5.9)	$3 - \frac{1}{m}$ (T. 5.10)	-

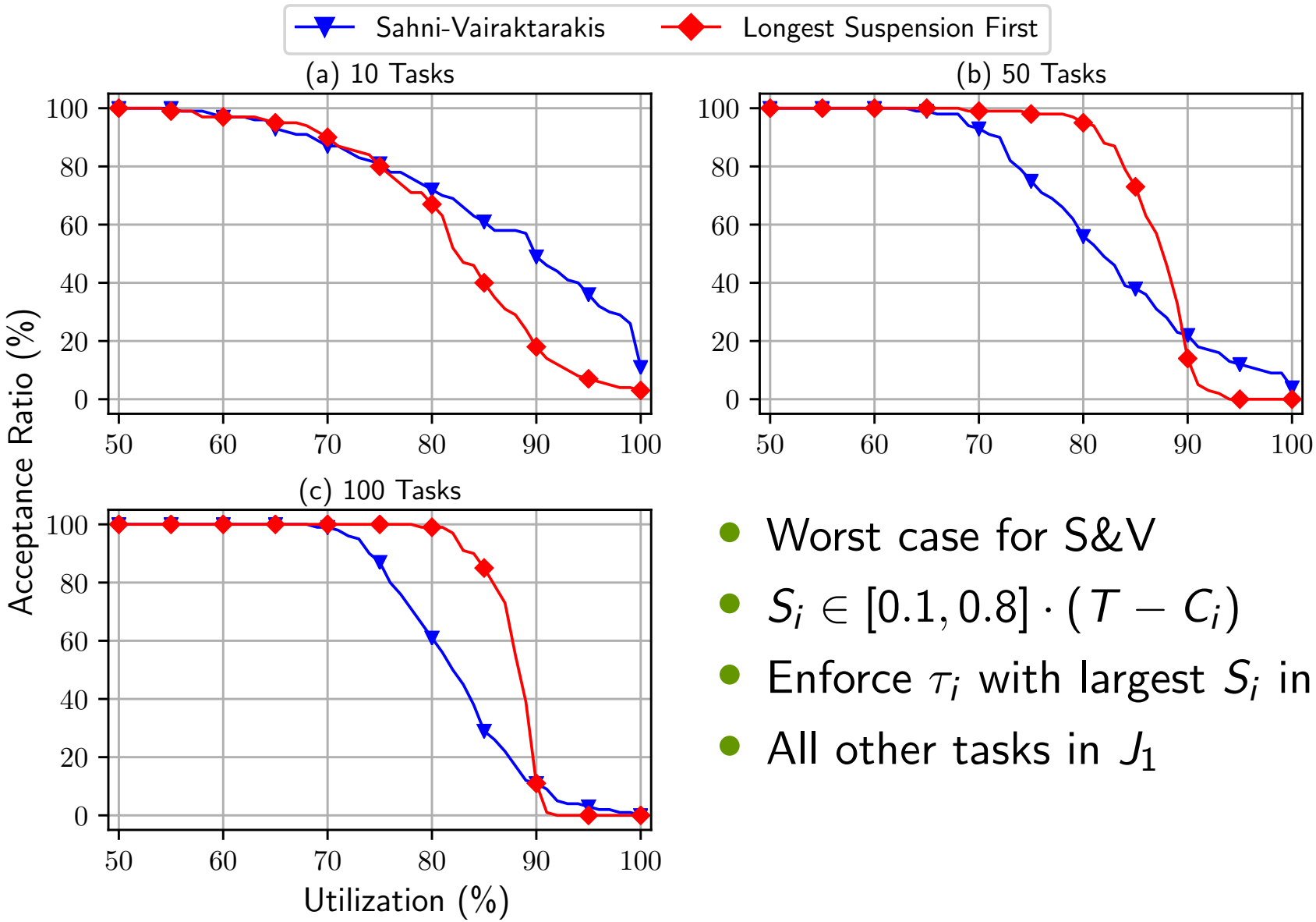
[42] Sahni and Vairaktarakis 1996

Evaluation



- UUniFast
- Frame T = 1000ms
- $C_i = T \cdot U_i$
- $C_{i,1} \in [0.1, 0.9] \cdot C_i$
- $C_{i,2} = C_i = C_{i,1}$
- $S_i \in [I_{min}, I_{max}] \cdot (T - C_i)$

Evaluation - Enforced Worst Case for S&V



- Worst case for S&V
- $S_i \in [0.1, 0.8] \cdot (T - C_i)$
- Enforce τ_i with largest S_i in J_2
- All other tasks in J_1

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Thank You!