# An Empirical Investigation of Eager and Lazy Preemption Approaches in Global Limited Preemptive Scheduling

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Vetenskapsrådet

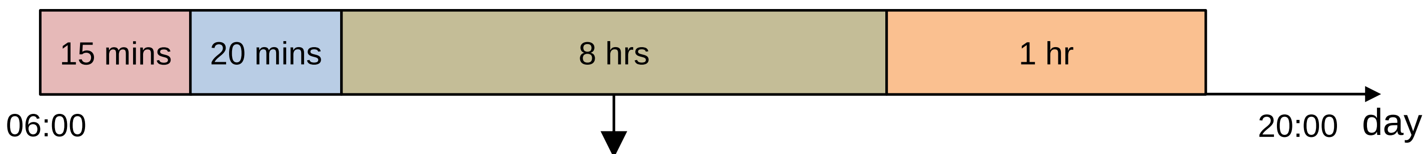
# We do Scheduling Everyday!

15 mins

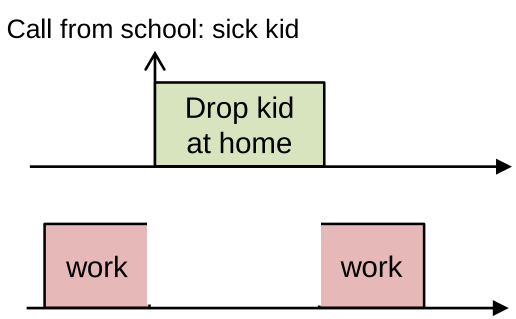
20 mins

8 hrs

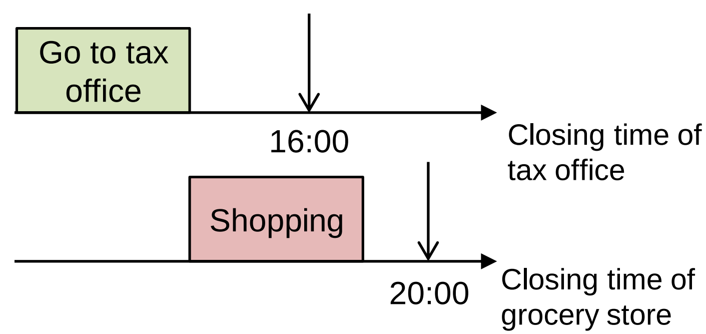
1 hr




## Priority based scheduling




## Deadline based scheduling



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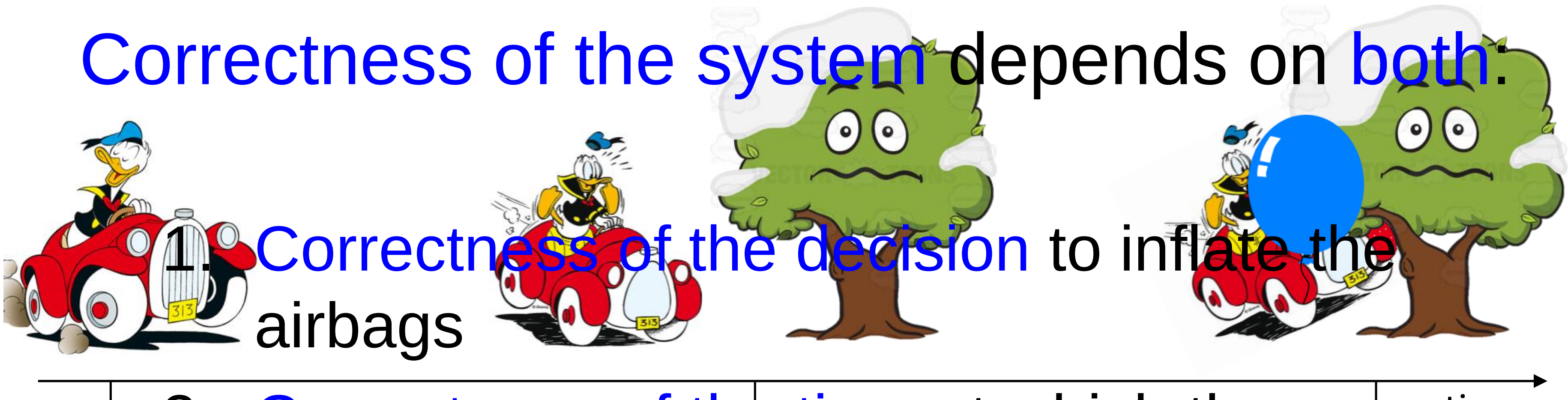
# Real-time Systems

Correctness of the system depends on both:



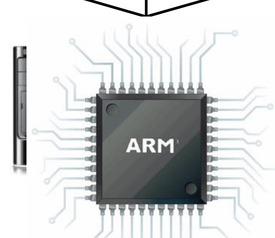

1. Correctness of the decision to inflate the airbags
2. Correctness of the time at which the decision is implemented

Computer programs called “tasks”

Detect the crash

Evaluate its intensity

Inflate the airbags

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# Real-time Scheduling

- Fewer computers than the number of tasks!
- Need to schedule the tasks such that deadlines are not missed
- For example tasks are typically executed highest priority first or earliest deadline first
- Schedulability test determines if a taskset meets deadlines under a given scheduling algorithm

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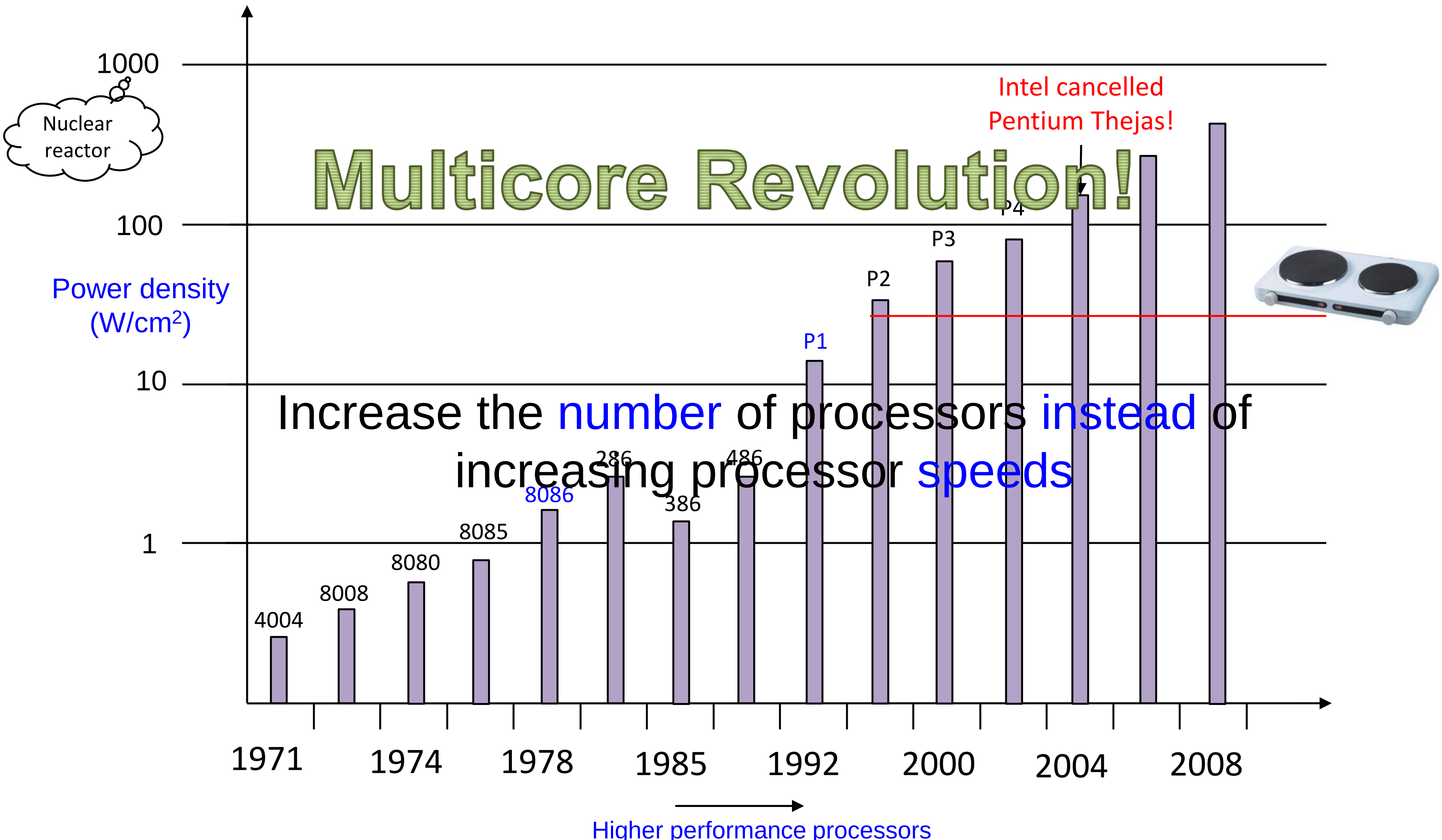
# Faster Computers vs. Power Demand




**Multicore Revolution!**

Increase the number of processors instead of increasing processor speeds

(adapted from Marko Bertogna's PhD thesis)

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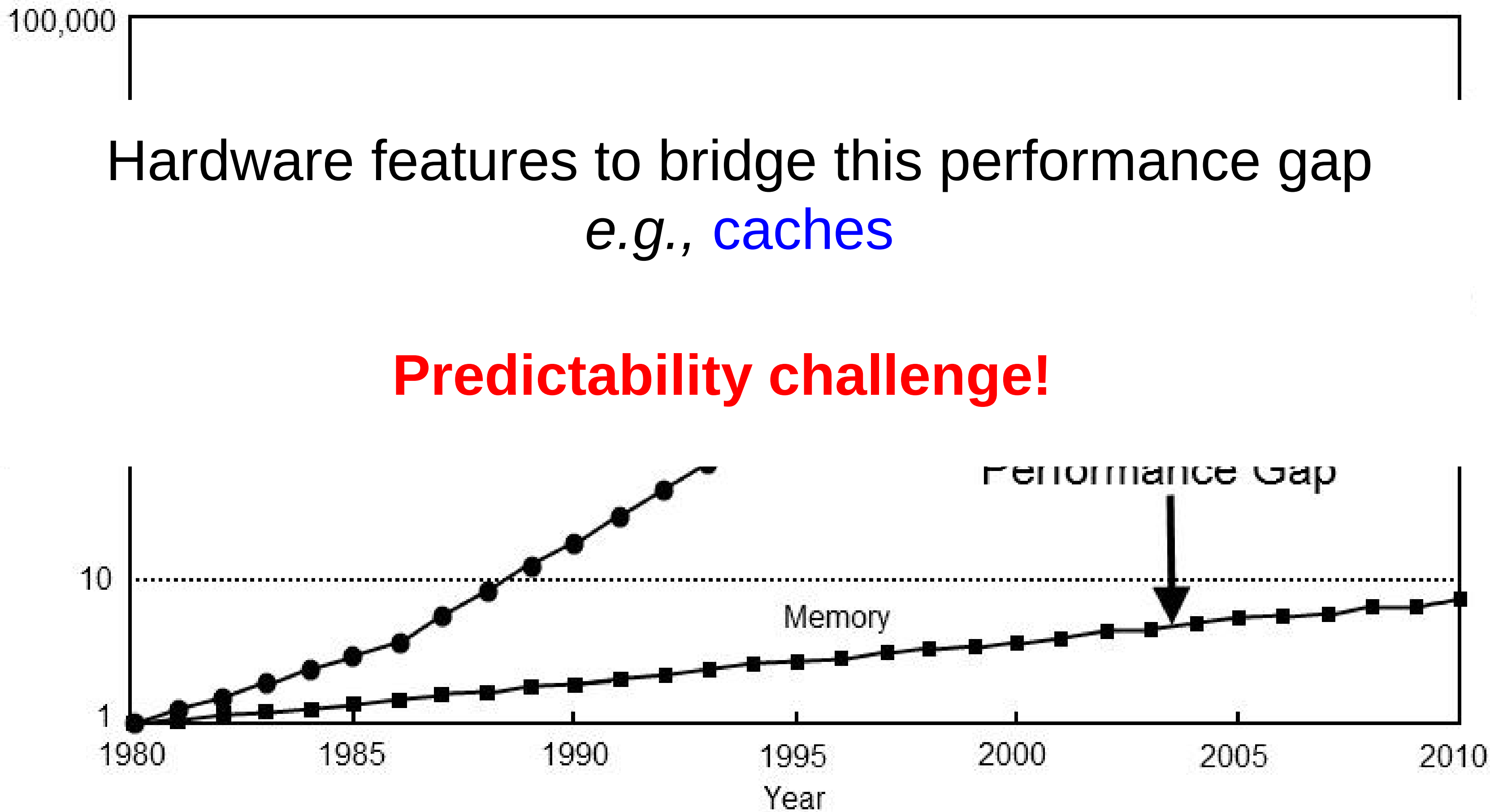
# Processor to Memory Performance Gap



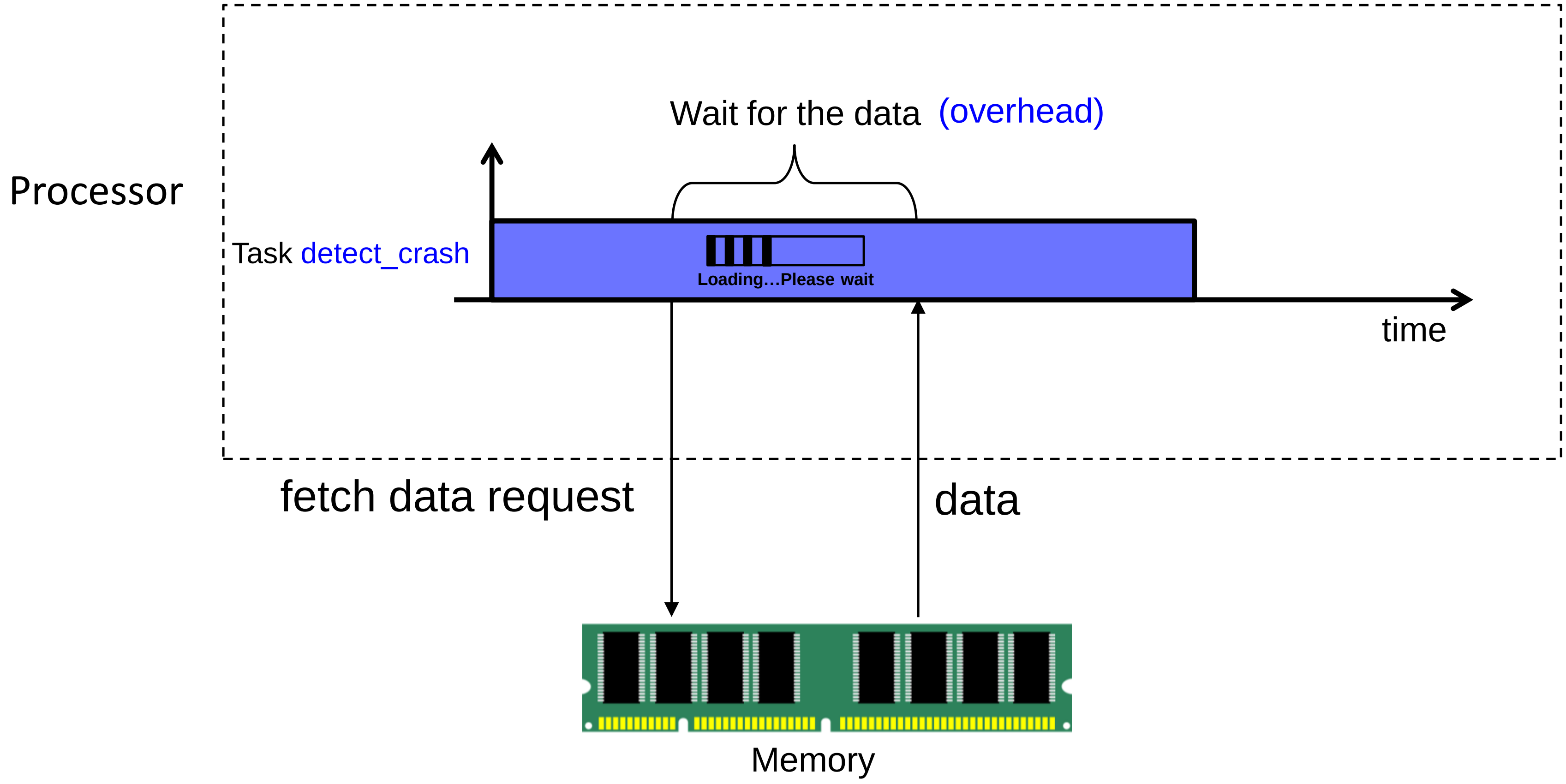

Hardware features to bridge this performance gap

*e.g.*, caches

**Predictability challenge!**

*Computer Architecture: A Quantitative Approach* by John L. Hennessy, David A. Patterson, Andrea C. Arpaci-Dusseau

# Processor to Memory Performance Gap





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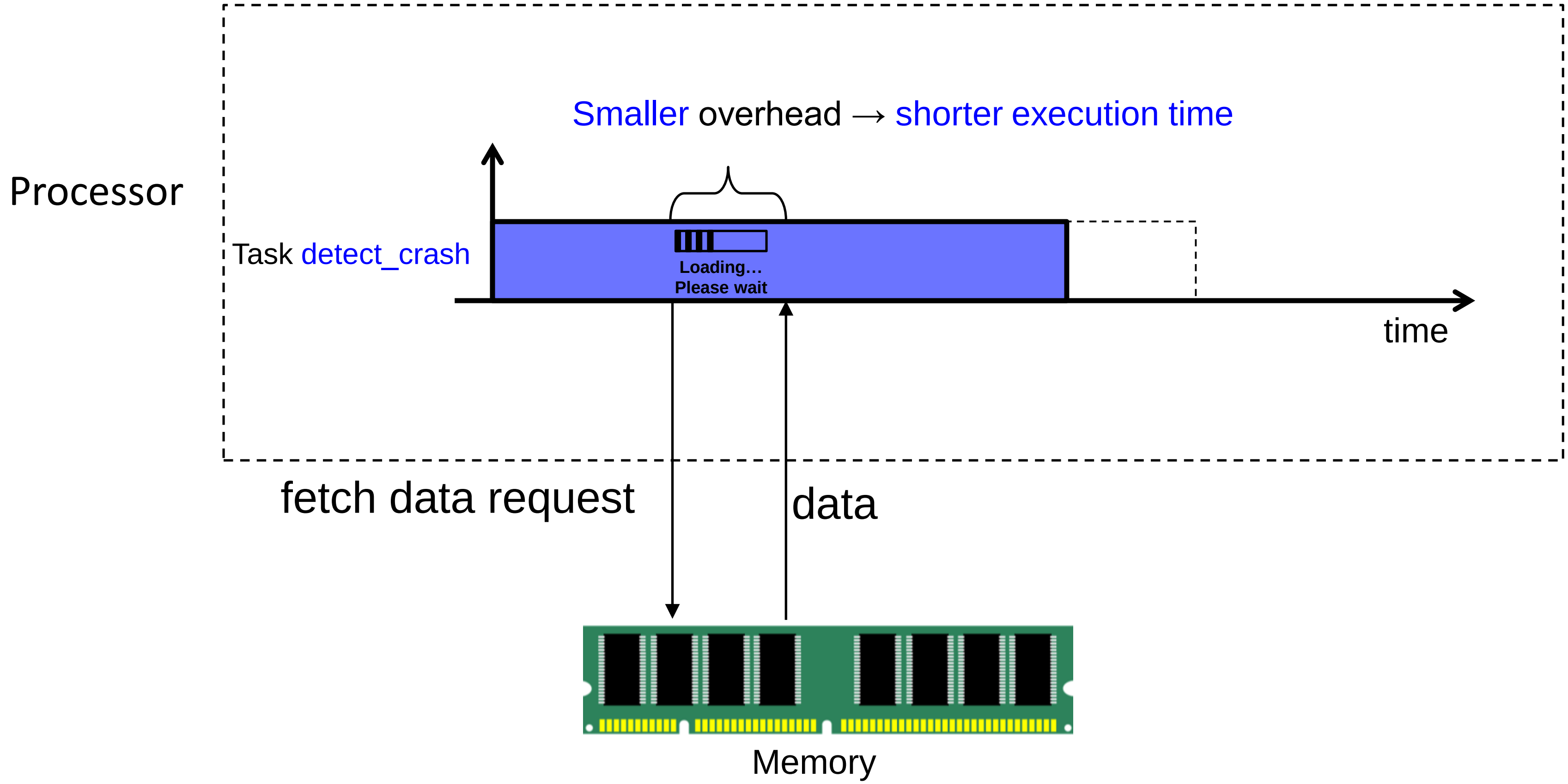
# Processor to Memory Performance Gap





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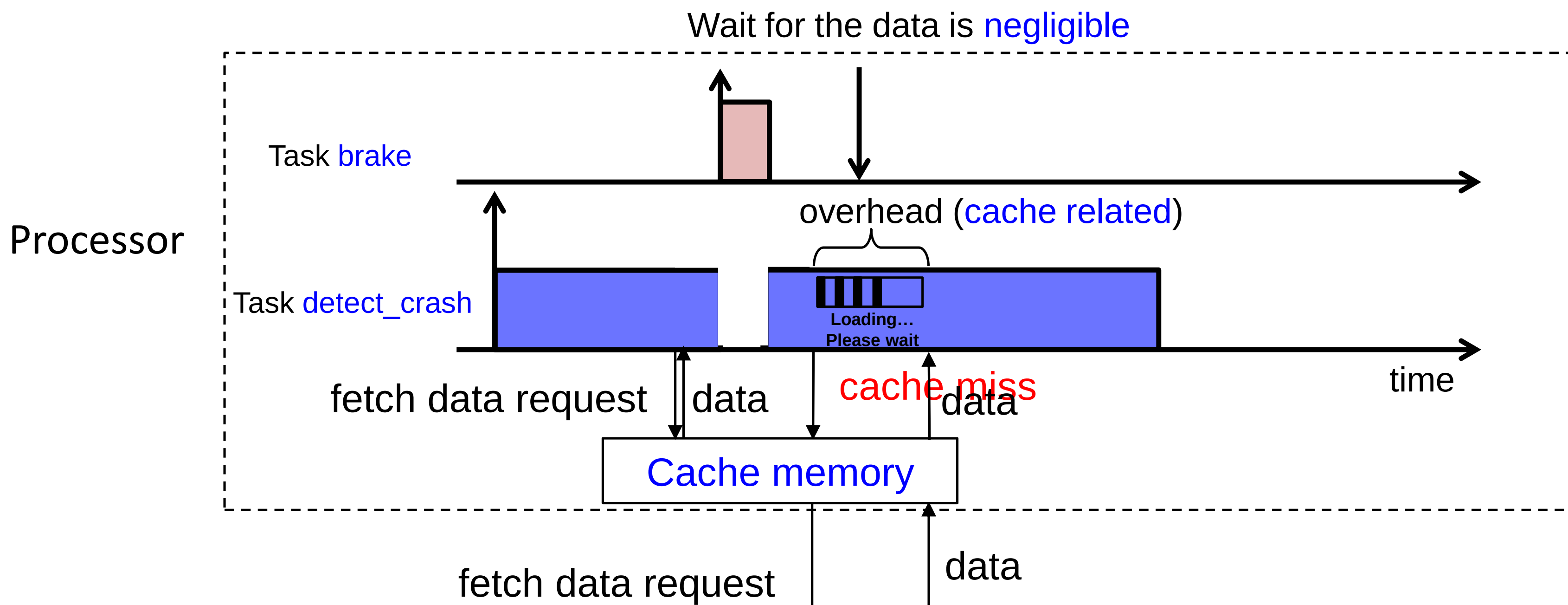
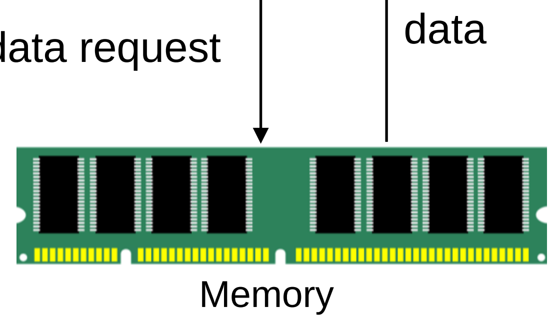
# Bridging the Processor to Memory Performance Gap




**Alternative 1**: build predictable hardware *e.g.,* PRETS

**Alternative 2**: efficient resource allocation & overhead accounting

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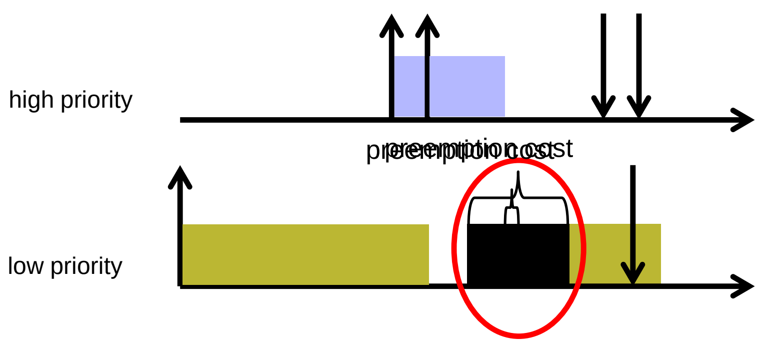
# Motivation

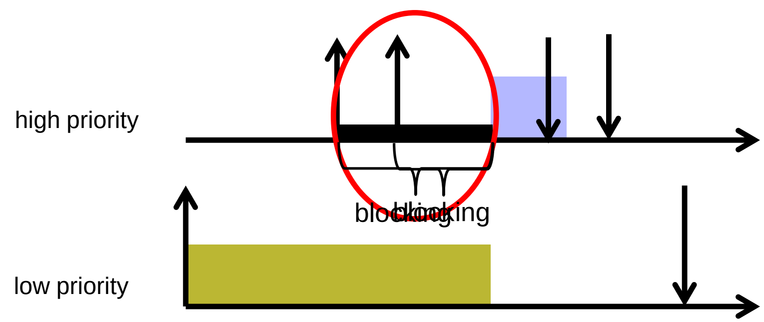
## Preemptive Scheduling

- ☺ Zero blocking: high schedulable utilization
- ☹ High runtime overhead: preemption costs
- ☹ Difficult to perform timing analysis
- ☹ Difficult to demonstrate predictability and safety: multicores

## Non-Preemptive Scheduling

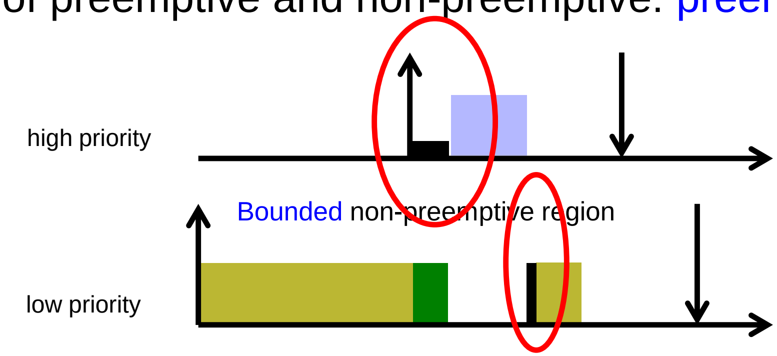
- ☺ Low runtime overhead: zero preemption costs
- ☺ Relatively easier to perform timing analysis
- ☺ Preferred by many safety standards
- ☹ Increased blocking: low schedulable utilization




## Solution: Limited-Preemptive Scheduling

- ☺ Best of preemptive and non-preemptive: preempt only when necessary

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# Limited Preemptive Scheduling Models

- Preemption Threshold Scheduling (ThreadX, Wang and Saksena, 1999)
- Fixed Preemption Point Scheduling (Burns, 1994, Bril *et al.,* 2009, Yao *et al.,* 2011)

Our focus

- Floating Non-Preemptive Region Scheduling (Baruah, 2005)
- …

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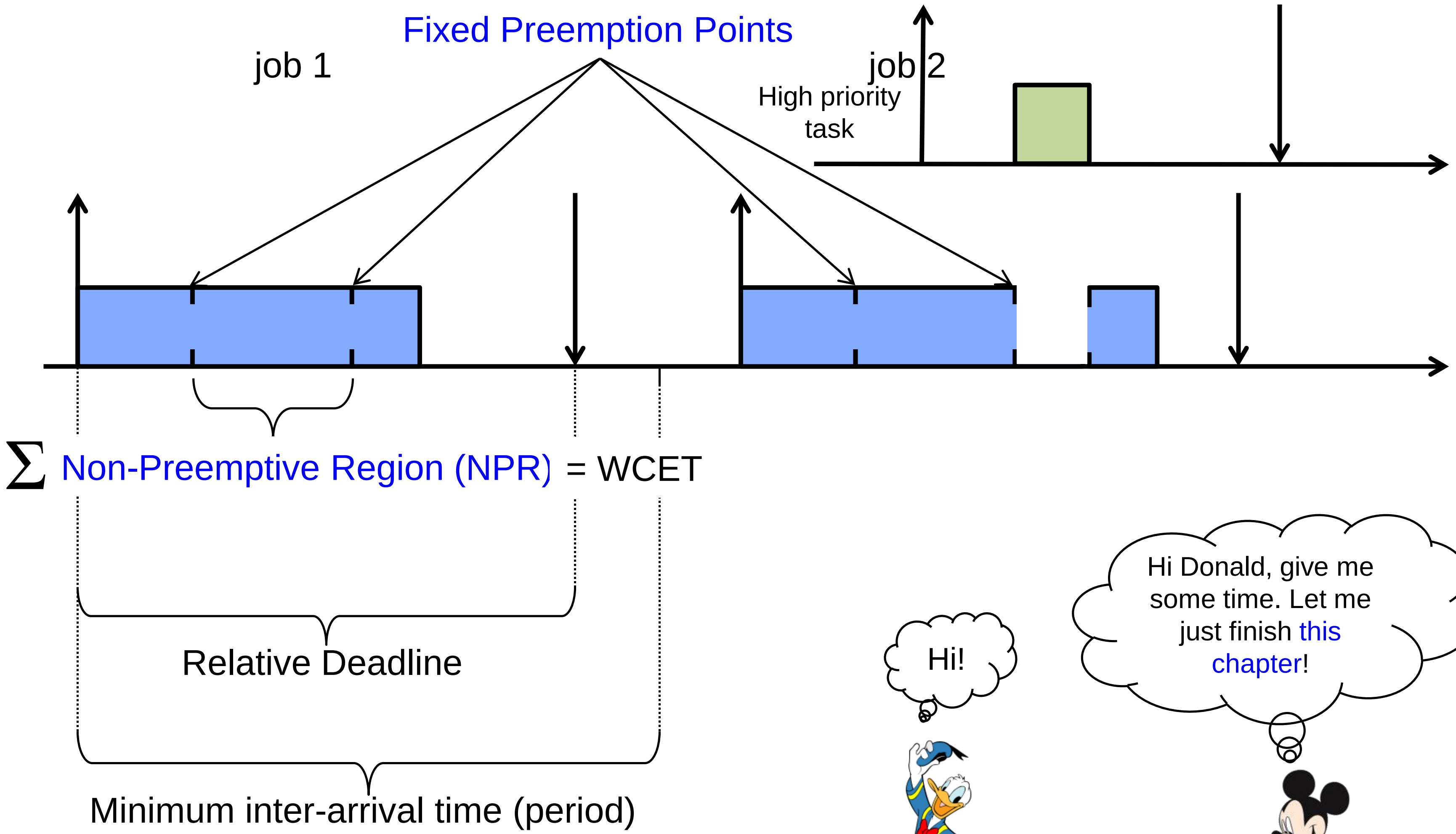
# Fixed Preemption Points Scheduling





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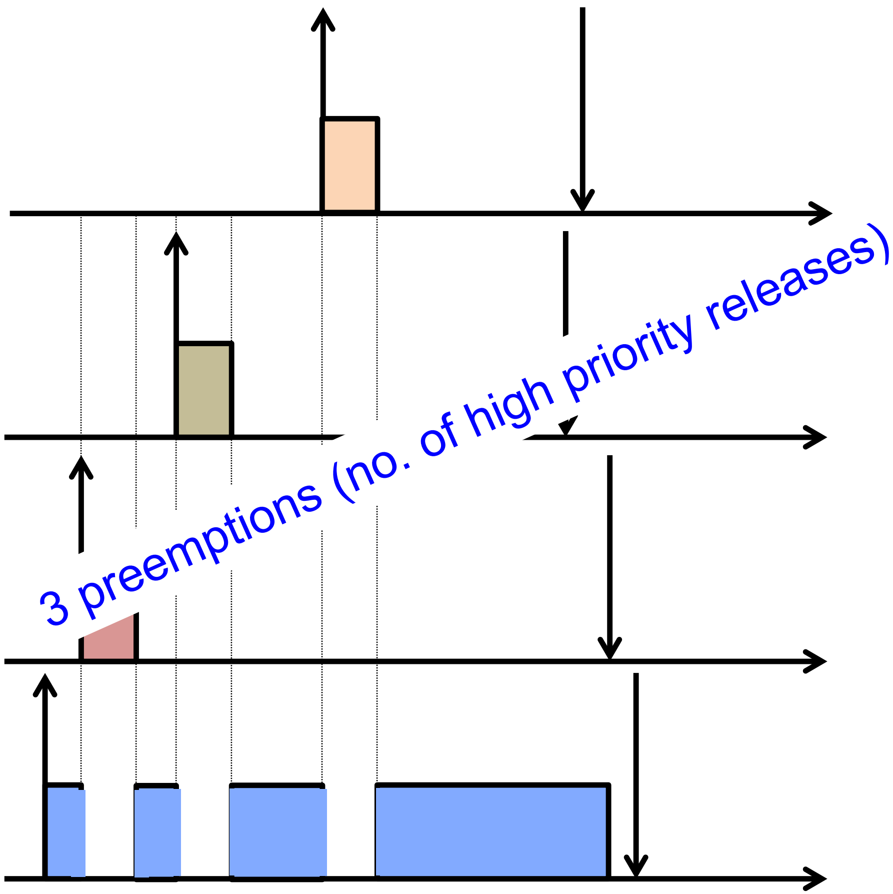
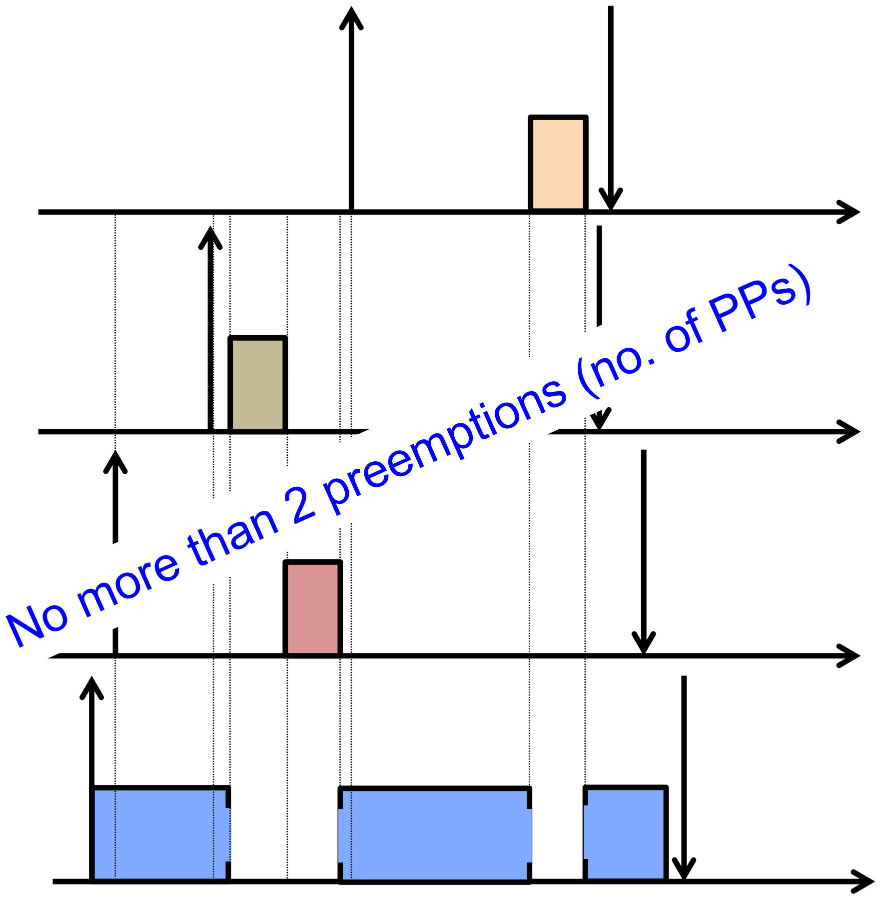
# Reduction in Preemptions

Fully Preemptive Scheduling




Fixed Preemption Points Scheduling

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# Limited Preemptive Scheduling Landscape

| | Fixed priority based scheduling | Deadline based scheduling |
|---|---|---|
| **Uniprocessor** | Limited Preemptive FPS | Limited Preemptive EDF |
| **Multiprocessor** | Global Limited Preemptive FPS | Global Limited Preemptive EDF |

Handling preemptions in global LP scheduling:

1. Eager Preemption Approach
2. Lazy Preemption Approach

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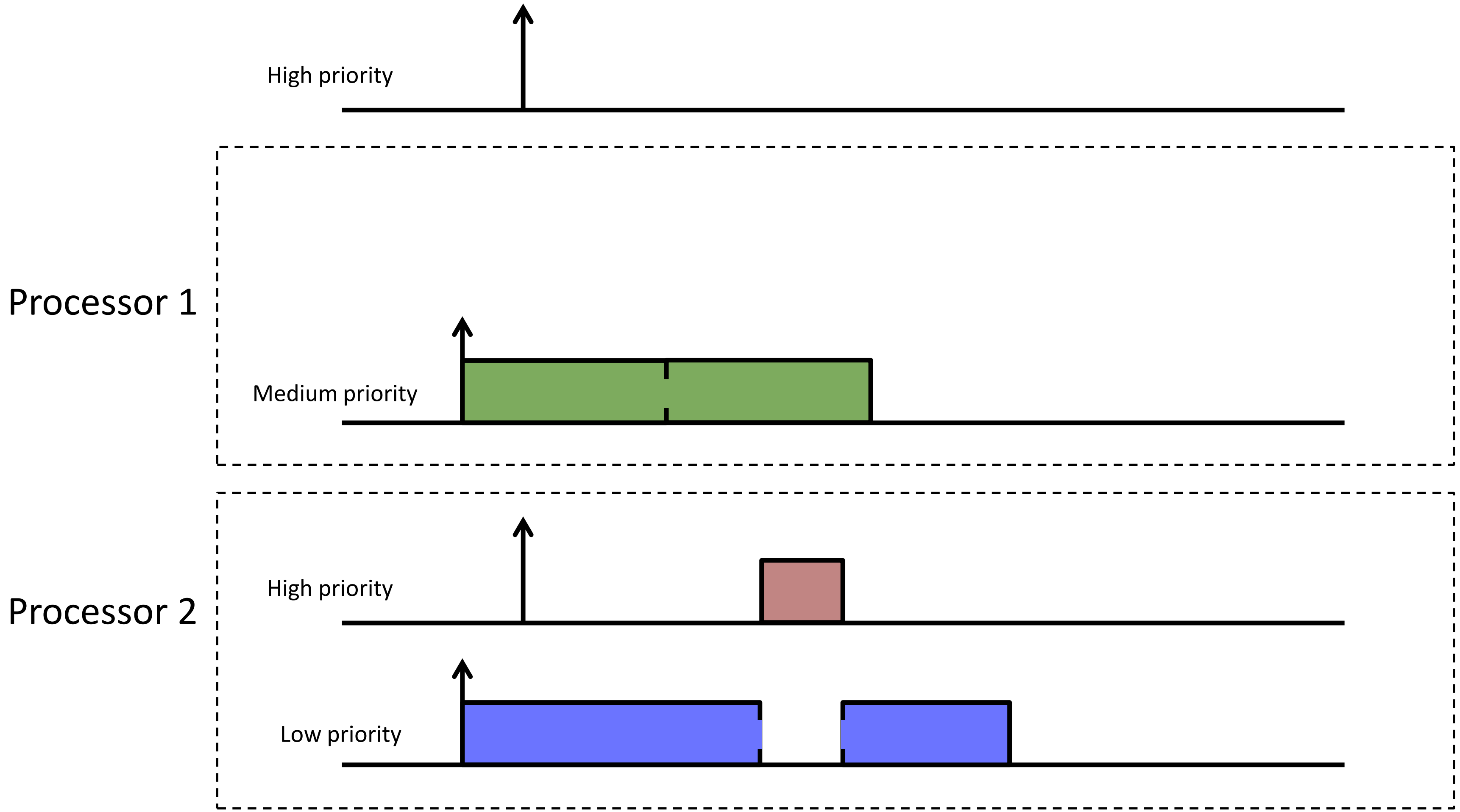
# Global Limited Preemptive Scheduling

Lazy Preemption Approach: wait to preempt the lowest priority task

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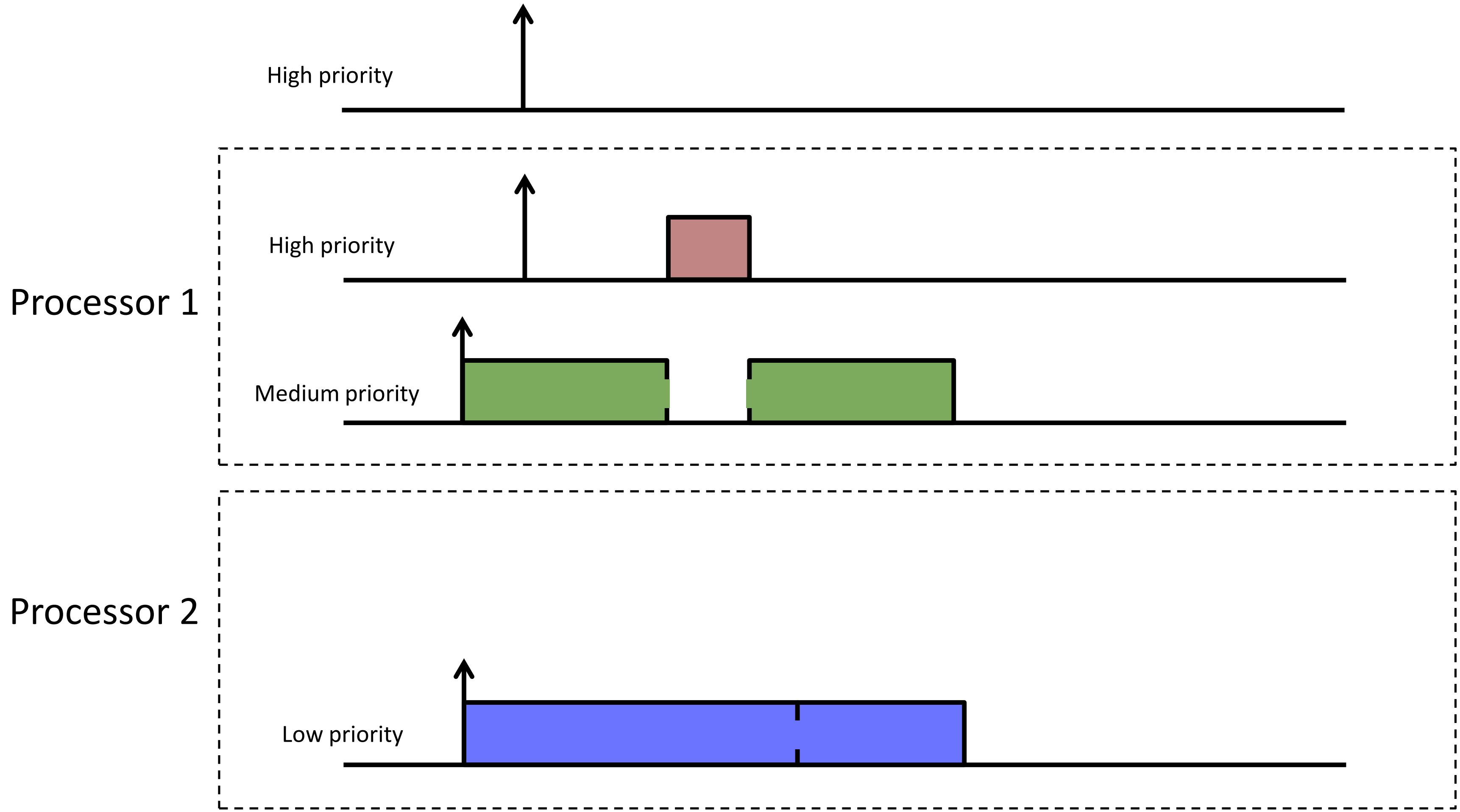
# Global Limited Preemptive Scheduling

Eager Preemption Approach: preempt the lower priority task that first finishes its NPR (not necessarily the lowest)

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# Advances in the Limited Preemptive Scheduling Landscape

| | | |
|---|---|---|
| **Uniprocessor** | Limited preemptive FPS<br>Burns'94, Bril *et al.*, RTSJ'09, Yao *et al.*, RTSJ'11 | Limited preemptive EDF<br>Baruah, ECRTS'05 |
| **Multiprocessor** | Global Limited Preemptive FPS<br><br>Marinho *et al.*, RTSS'13, Davis *et al.*, TECS'15, Thekkilakattil *et al.*, RTNS'15, Marinho, PhD Thesis'15, Serrano *et al.*, DATE'16 | Global Limited Preemptive EDF<br><br>Block et al., RTCSA'07<br>Thekkilakattil *et al.*, ECRTS'14,<br>Chattopadhyay *et al.*, RTNS'14,<br>Marinho, PhD Thesis'15 |

Focus on schedulability!

# Preemptive Behavior of FPS and EDF

… under the preemptive and limited preemptive paradigms
for eager and lazy approaches

| | |
|---|---|
| **Uniprocessors** | Buttazzo, RTSJ'05<br>(RM vs EDF: Judgement Day) |
| **Multiprocessors** | No significant work! |

How does the number of preemptions vary with the scheduling algorithm and approach to preemption on multiprocessors?

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# Experimental Setup

- Weighted metric to count preemptions:

$$W(p) = \frac{\sum_{\forall\Gamma} U(\Gamma)P(\Gamma, p)}{\sum_{\forall\Gamma} U(\Gamma)}$$

- Enables investigation of number of preemptions *w.r.t* a second parameter in addition to utilization

- Tasksets generated using Uunifast-Discard
- Periods in the range *5-500*
- Utilizations in the range *1* to *m/2* (in one case upto m)
- Schedule simulated for 10000 time units

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# Weighted Metric to Count Preemptions

$$W(p) = \frac{\sum_{\forall \Gamma} U(\Gamma) P(\Gamma, p)}{\sum_{\forall \Gamma} U(\Gamma)}$$

Number of preemptions generated by taskset $\Gamma$ *w.r.t* parameter p

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# Weighted Metric to Count Preemptions

Utilization of taskset $\Gamma$

$$W(p) = \frac{\sum_{\forall\Gamma} U(\Gamma) P(\Gamma, p)}{\sum_{\forall\Gamma} U(\Gamma)}$$

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# Experiments

We investigated how *weighted preemptions* vary with:

1. Varying utilizations
2. Varying number of tasks
3. Varying number of processors
4. Varying NPR lengths

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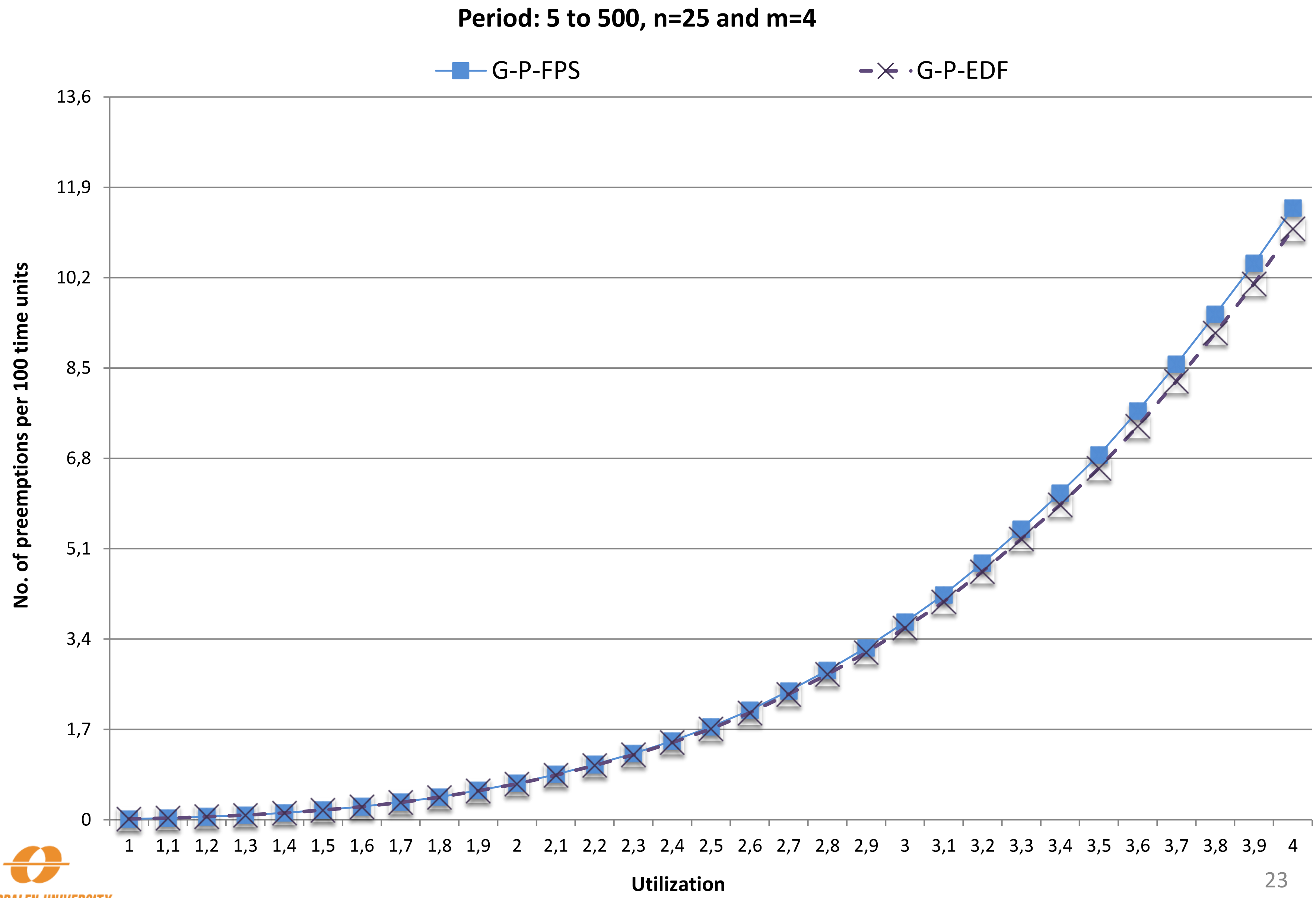
# Varying Utilization

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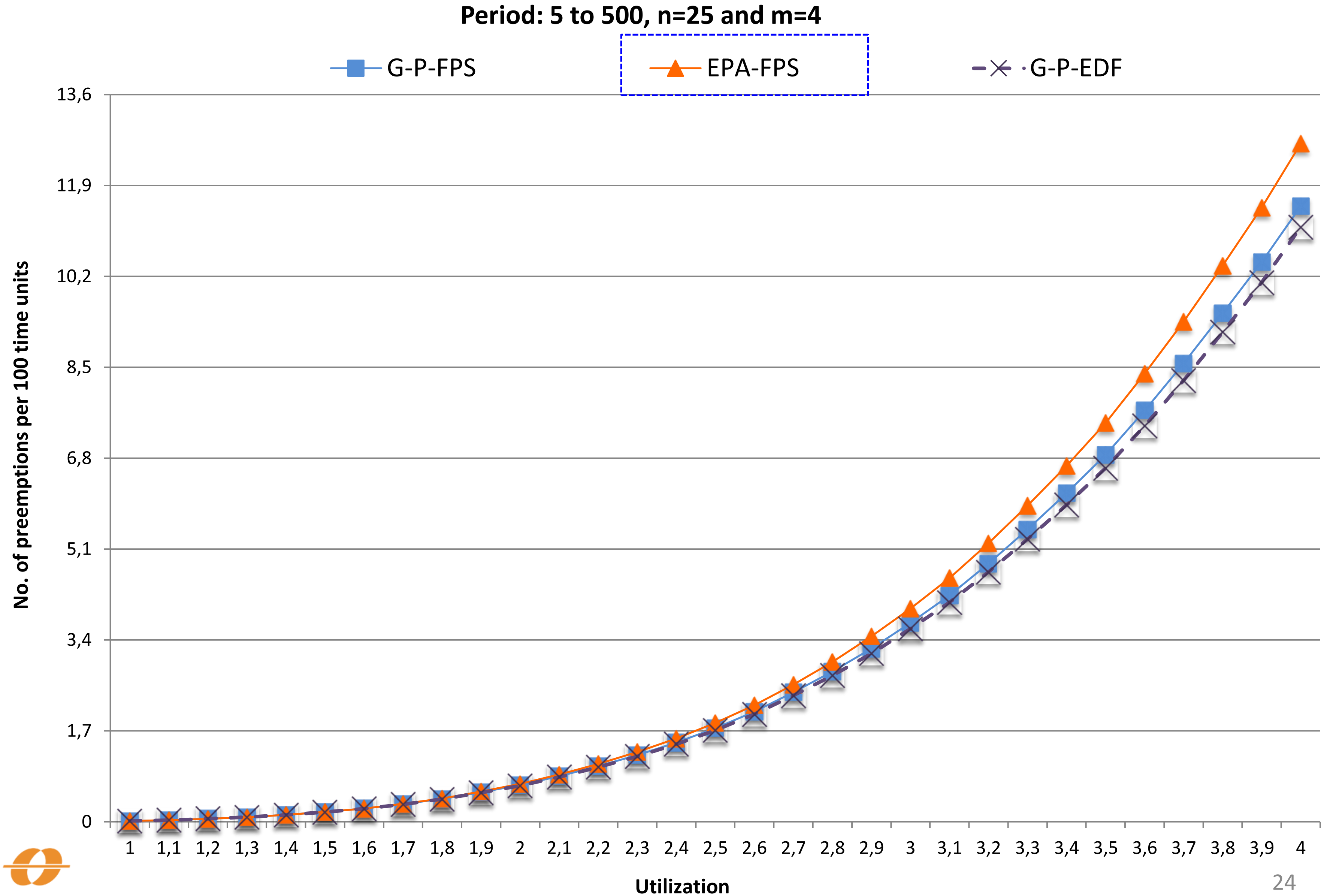


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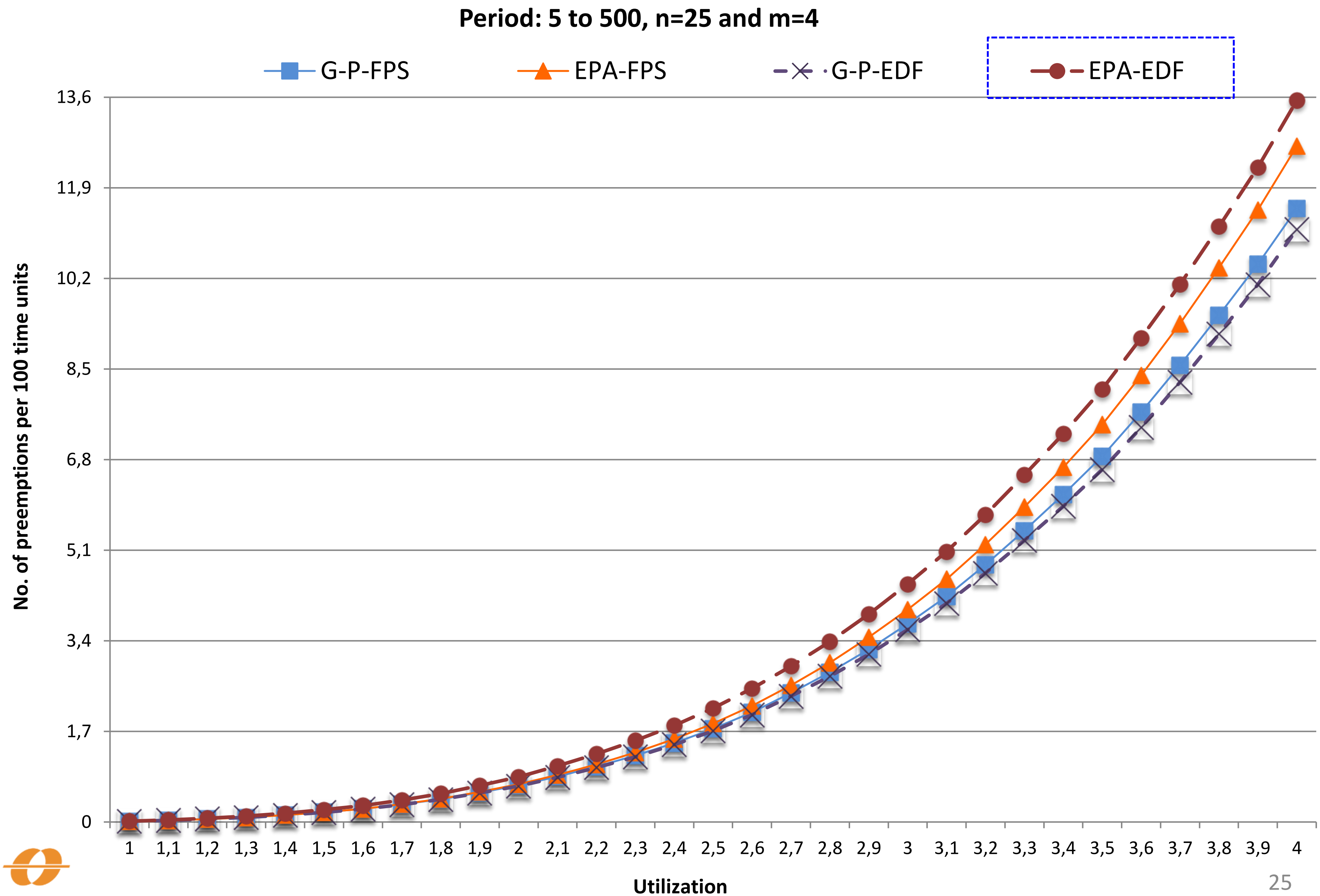




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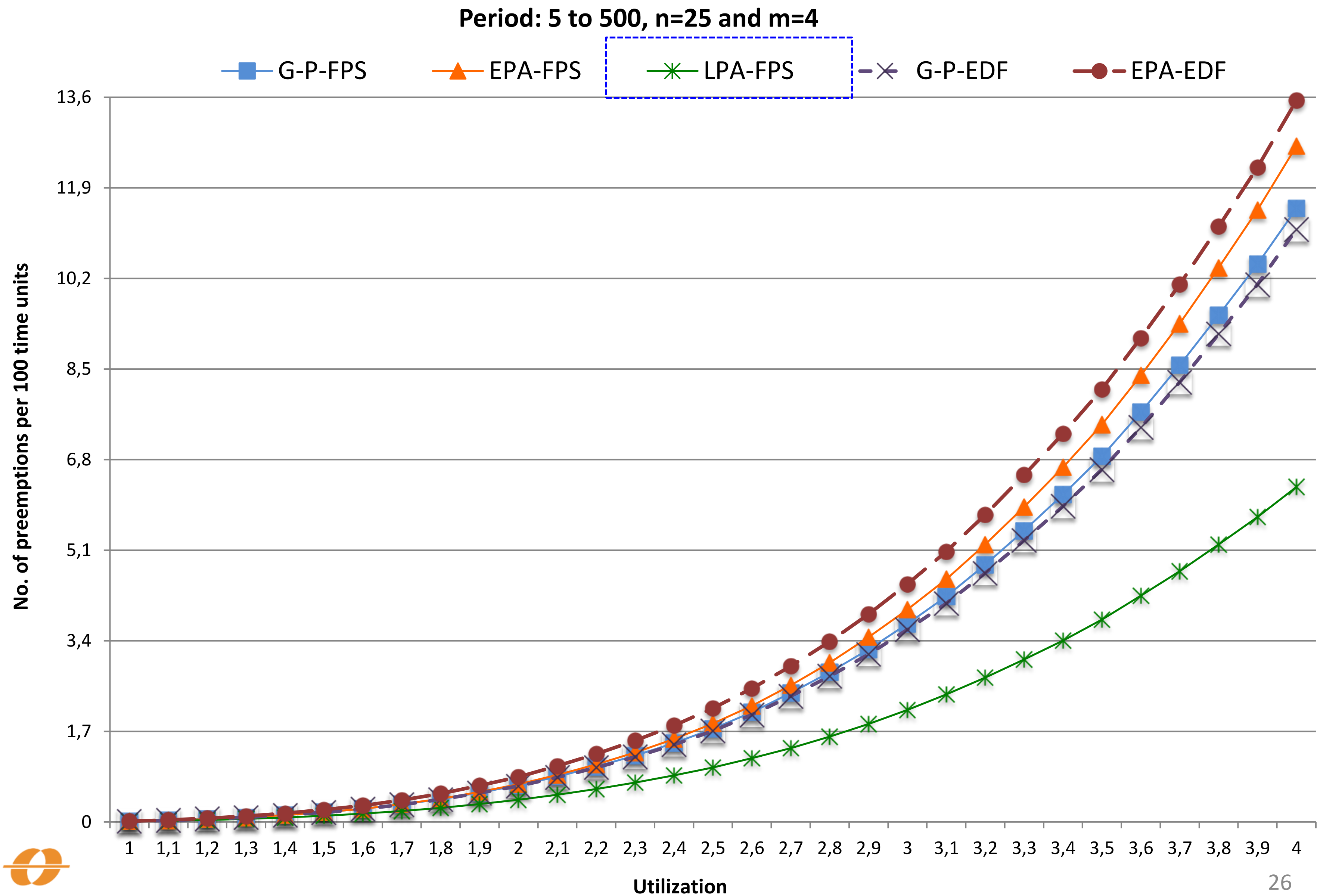


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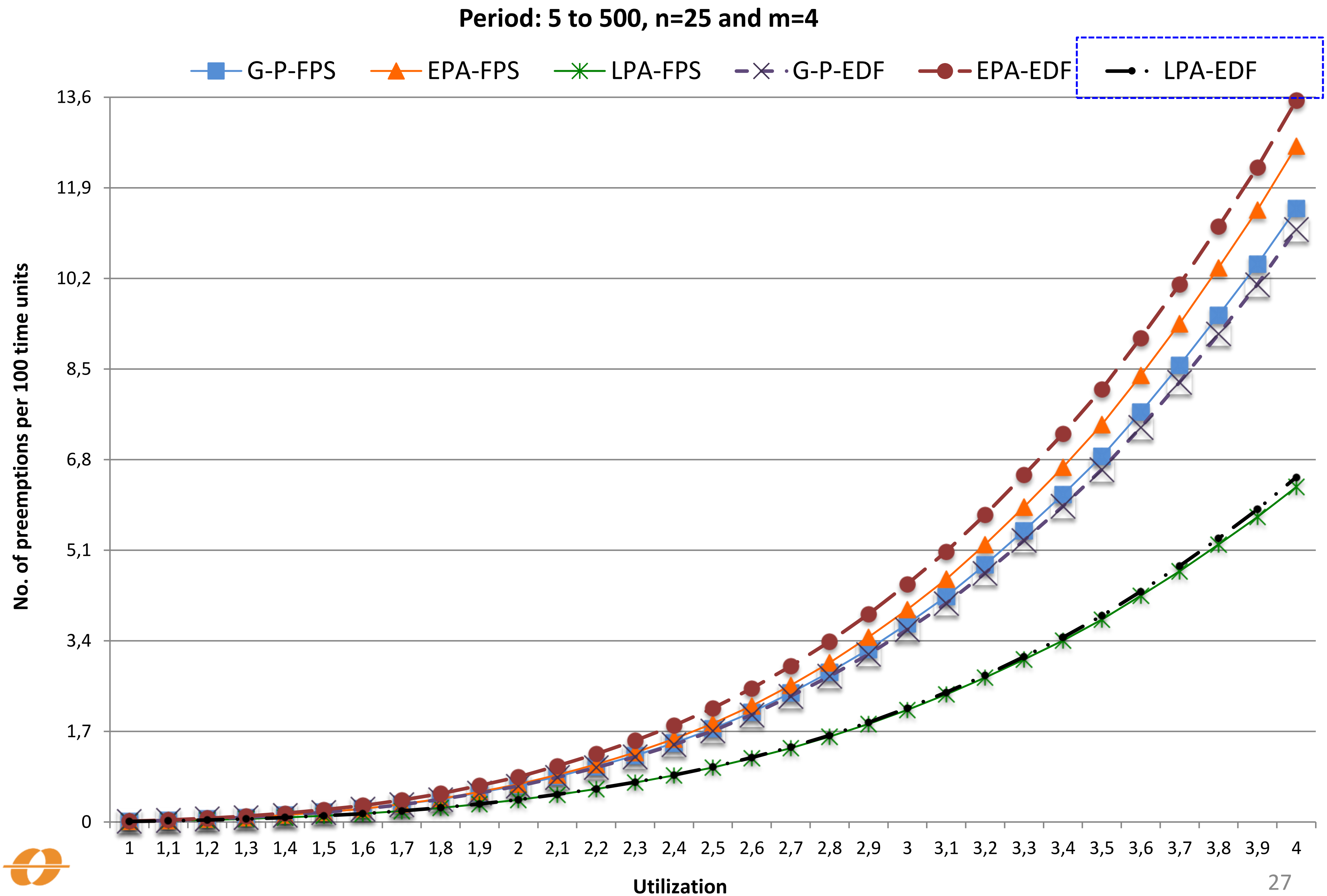


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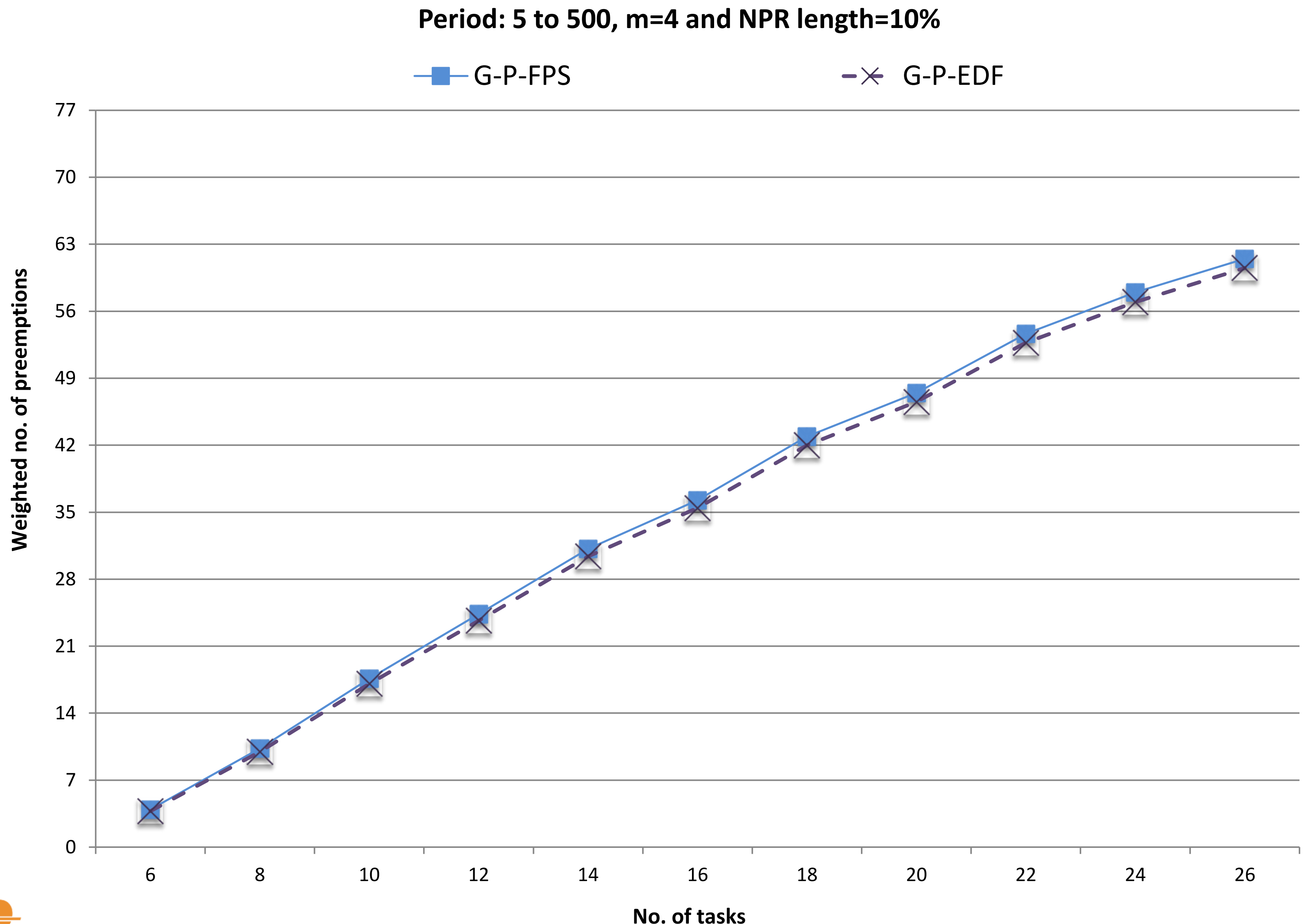
# Varying Number of Tasks

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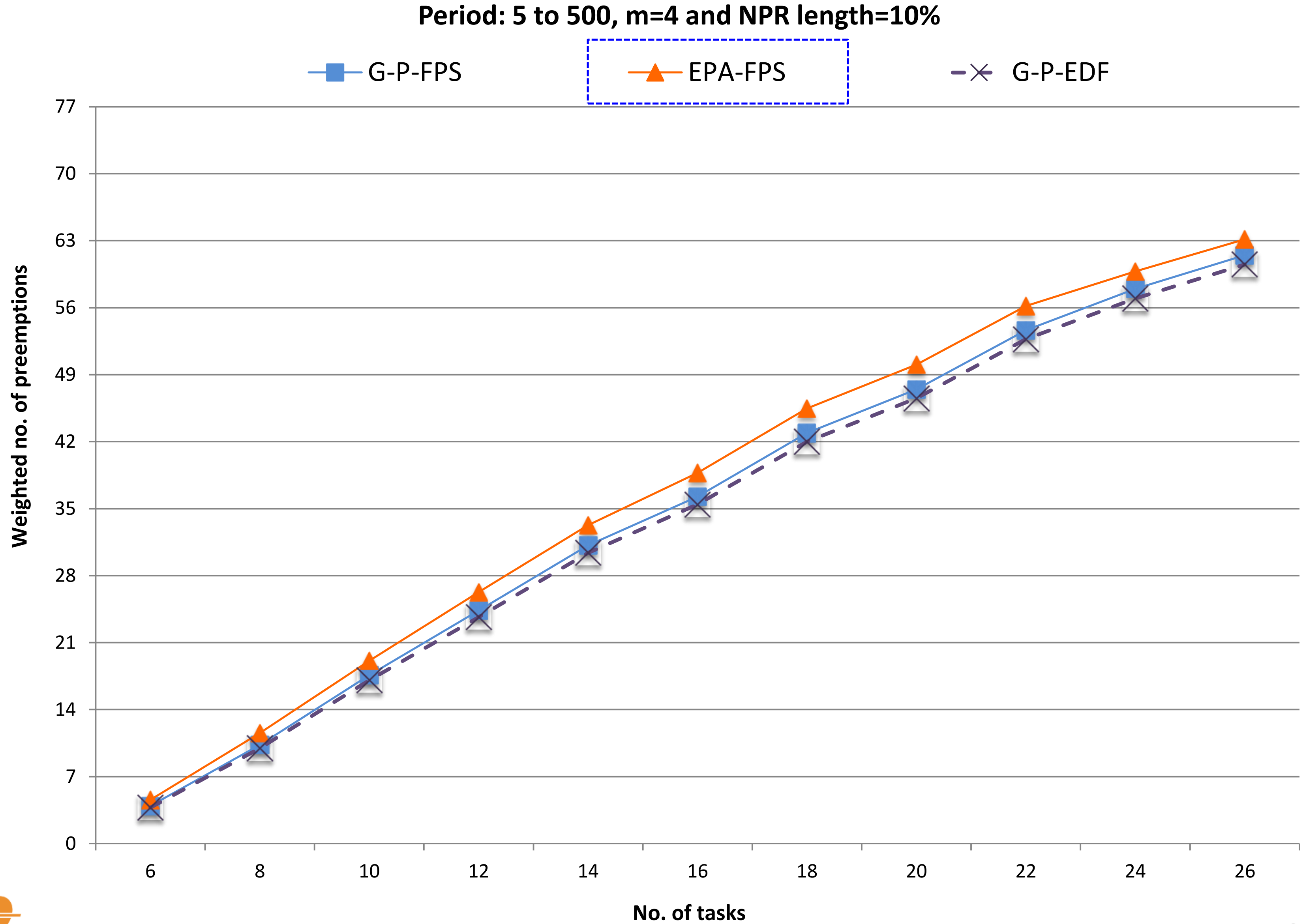


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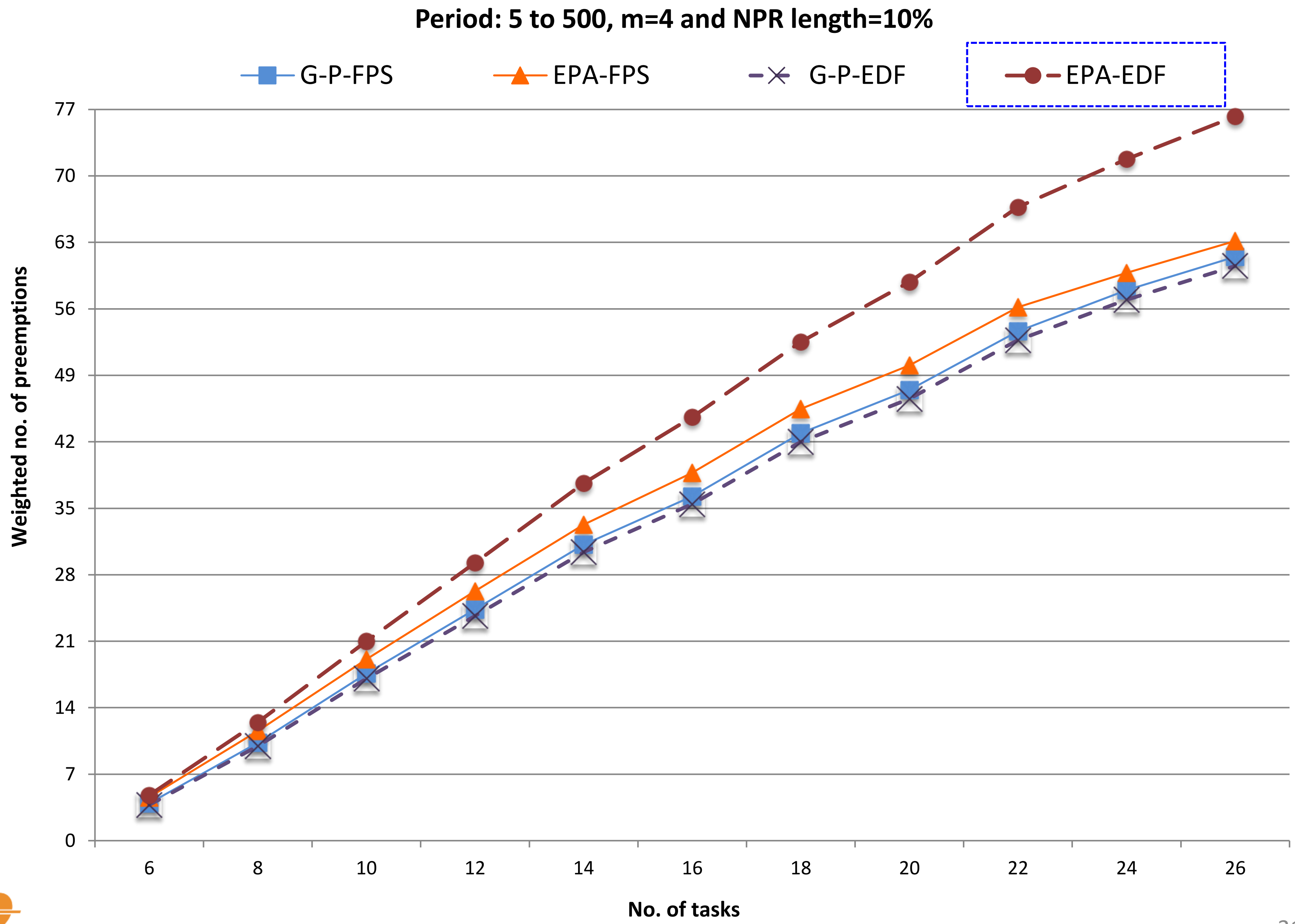


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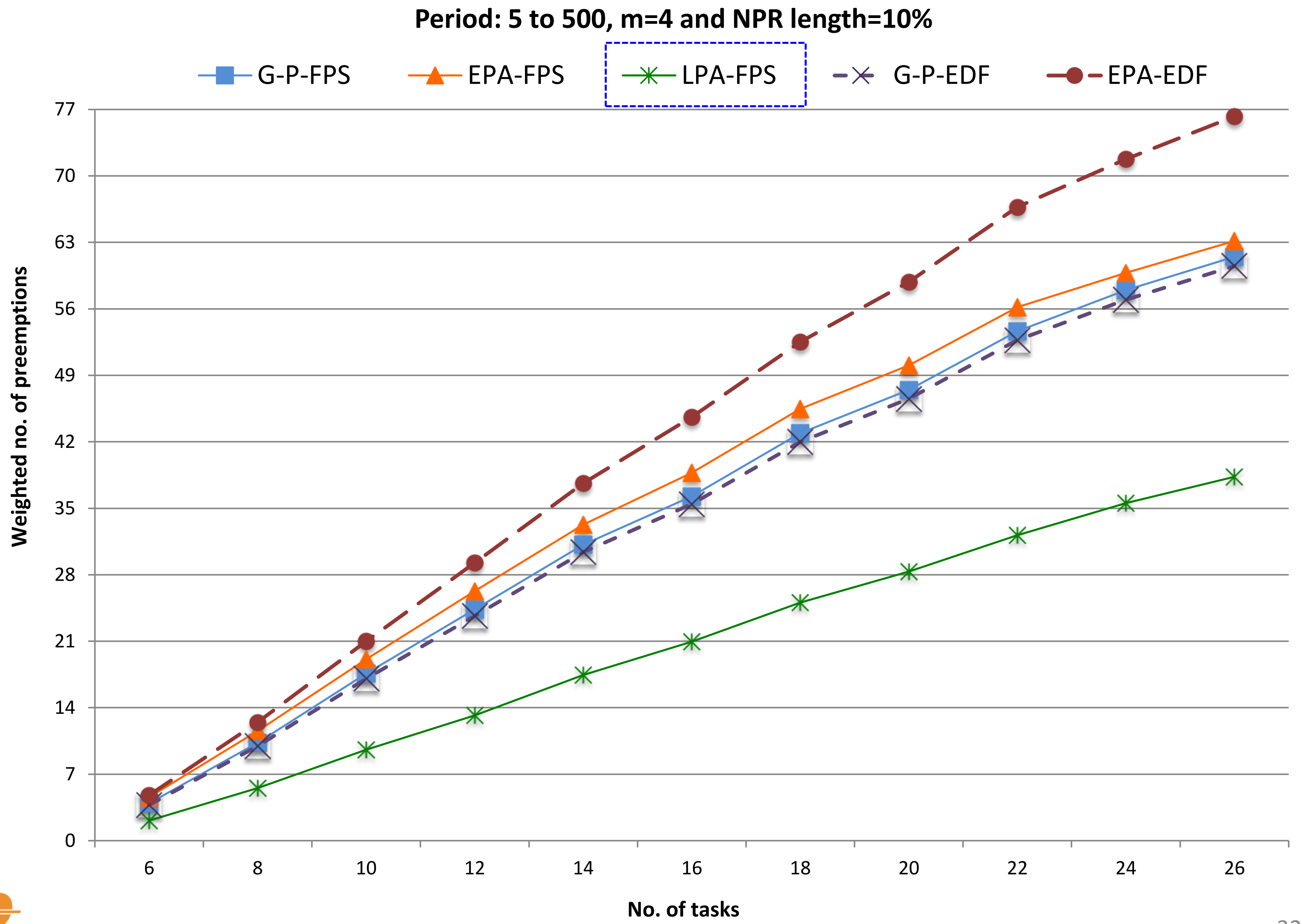


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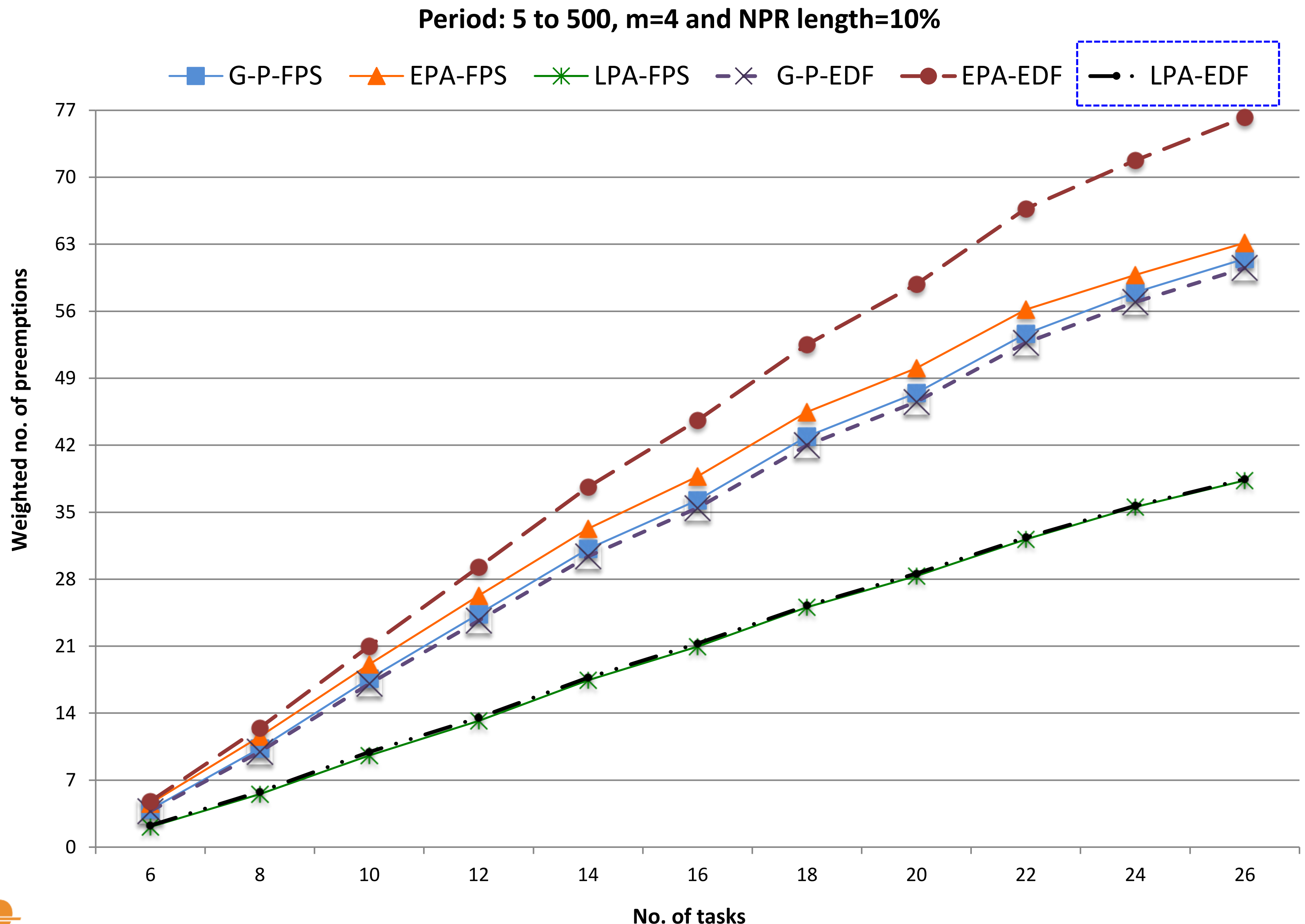
# Varying Number of Tasks

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# Experiments

We investigated how *weighted preemptions* vary with:

1. Varying utilizations
2. Varying number of tasks
3. Varying number of processors
4. Varying NPR lengths

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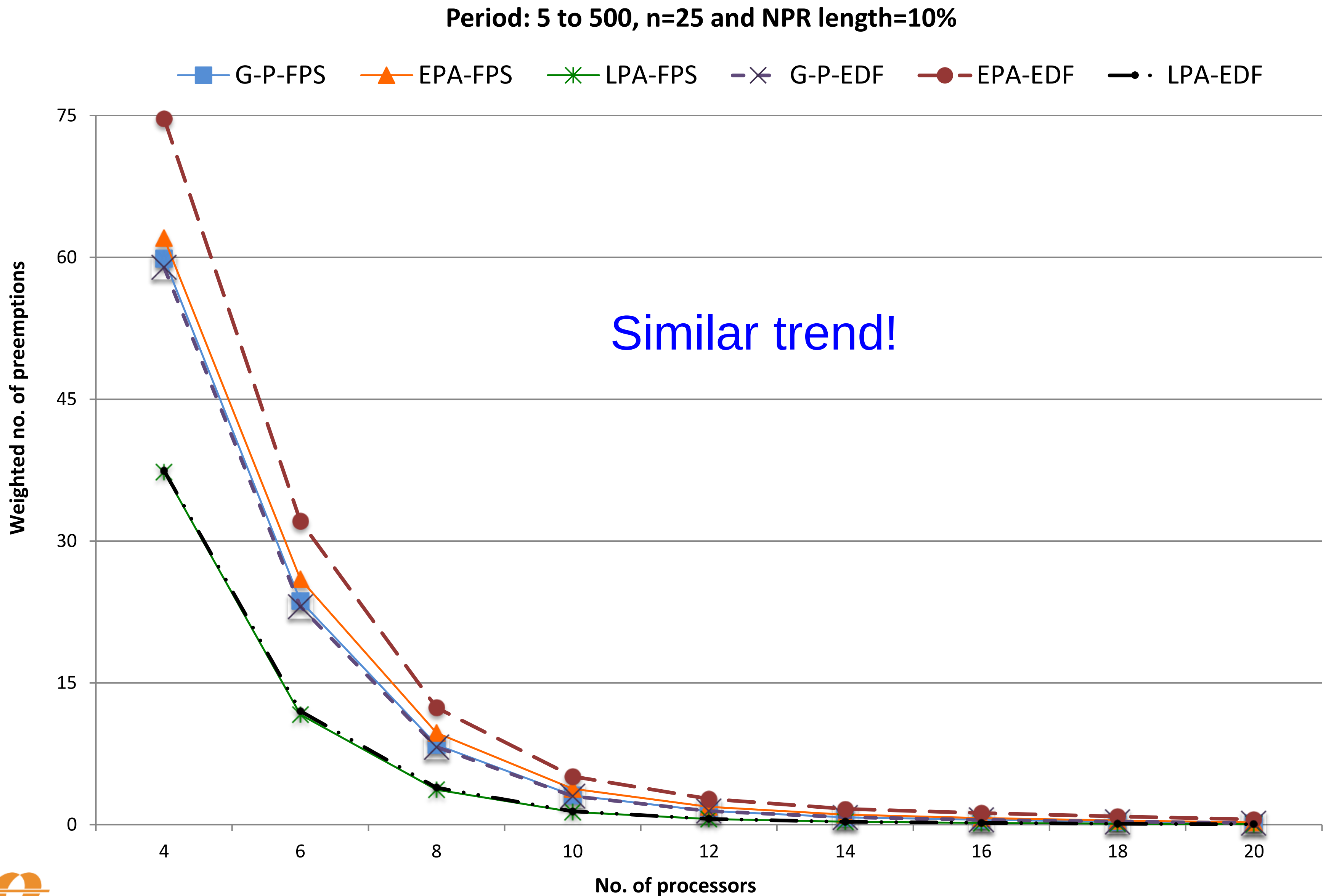
# Varying Number of Processors



# Experiments

We investigated how *weighted preemptions* vary with:

1. Varying utilizations
2. Varying number of tasks
3. Varying number of processors
4. Varying NPR lengths

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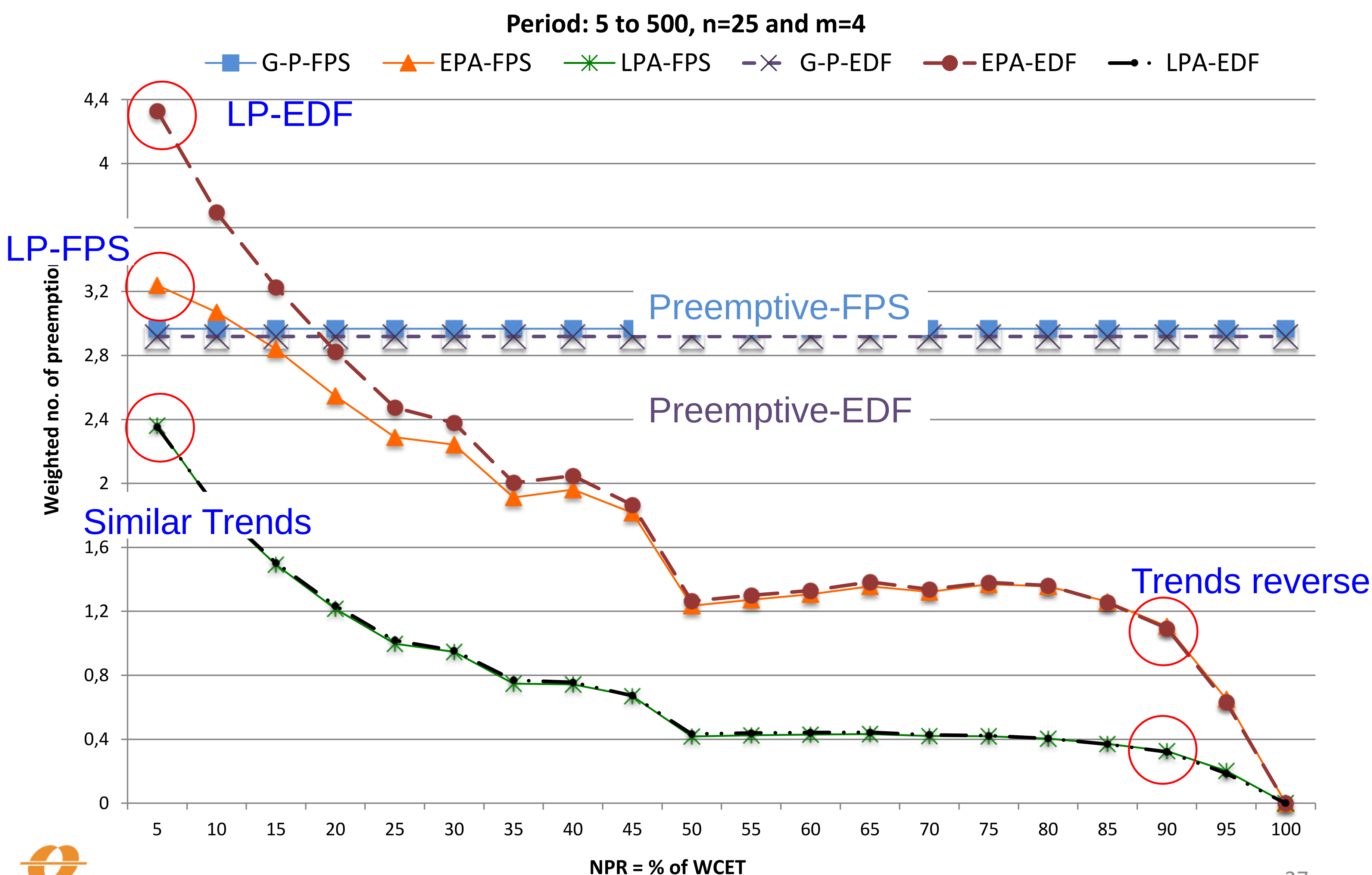
# Varying Lengths of NPRs

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# Observations

1. Eager preemption approach generates most preemptions while lazy preemption approach generates least

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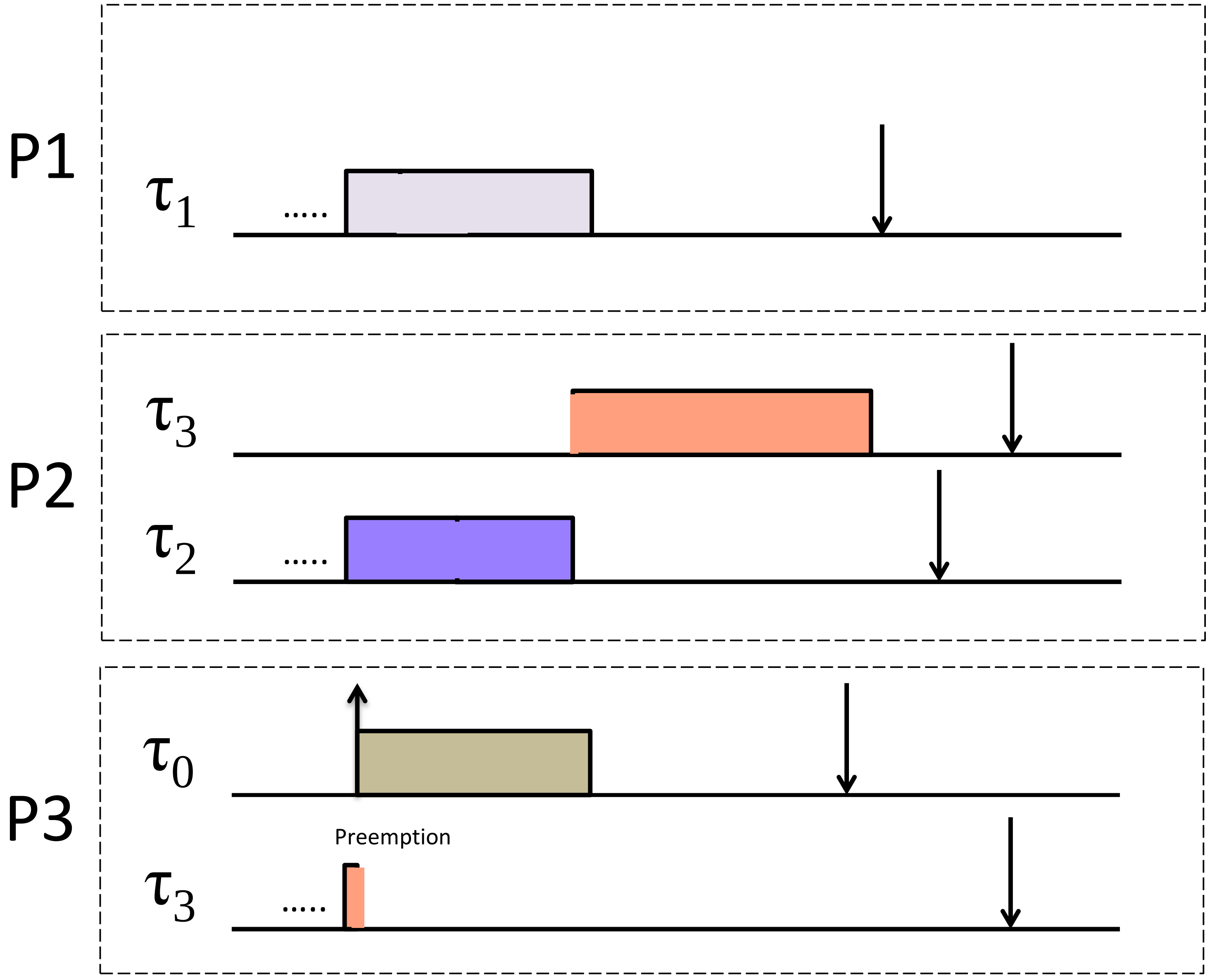
# Preemptive Scheduling

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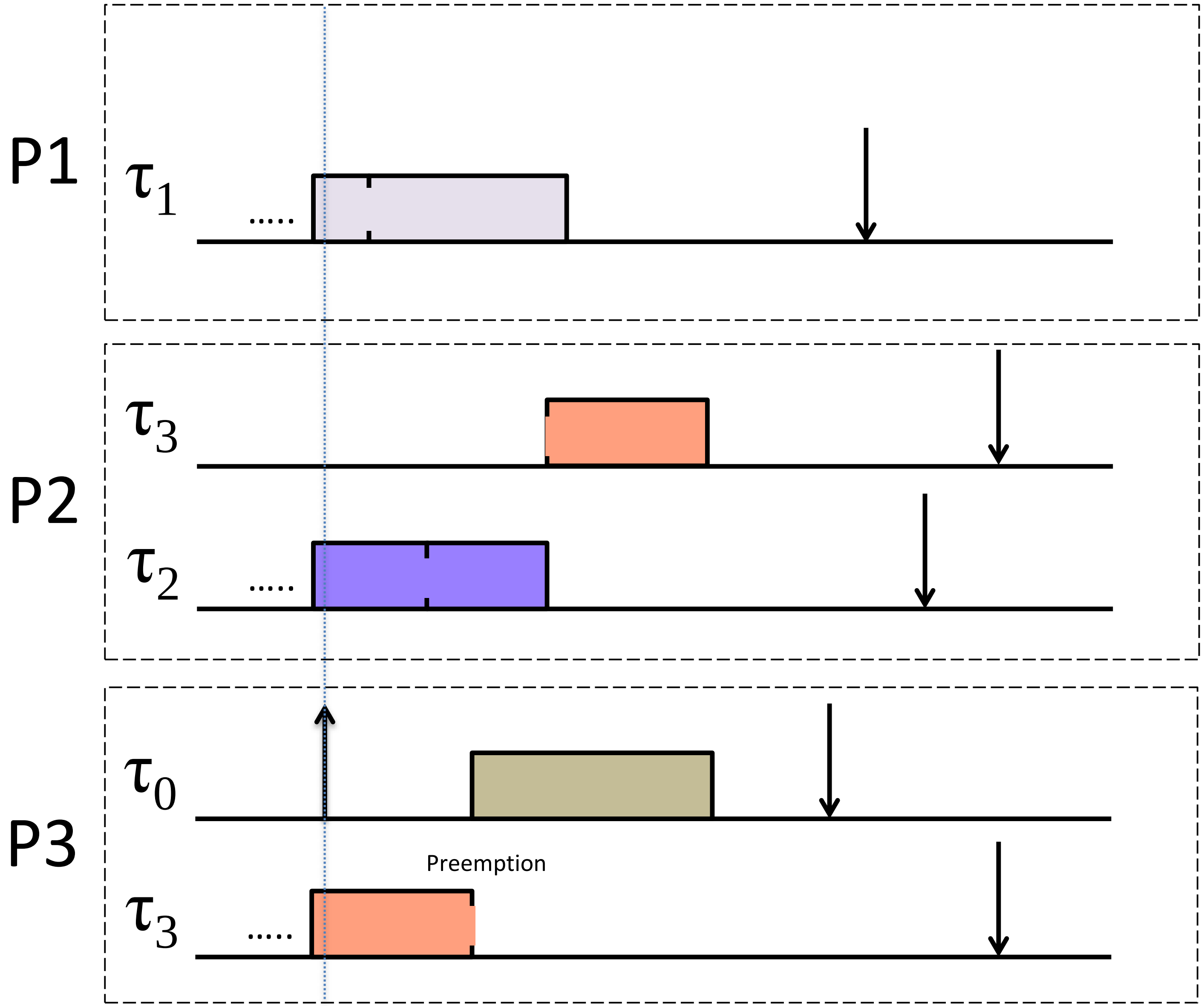
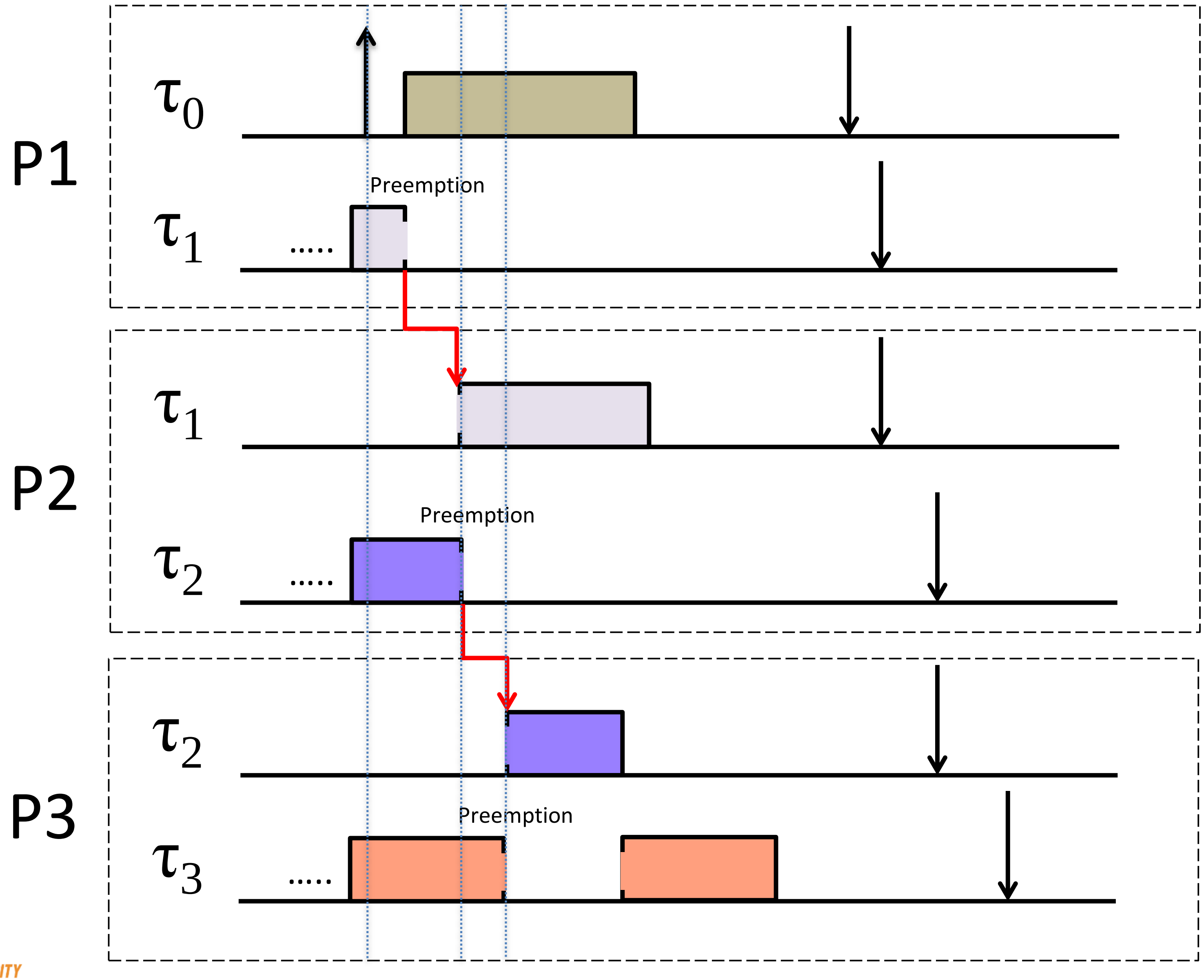
# Lazy Preemption Approach



# Eager Preemption Approach



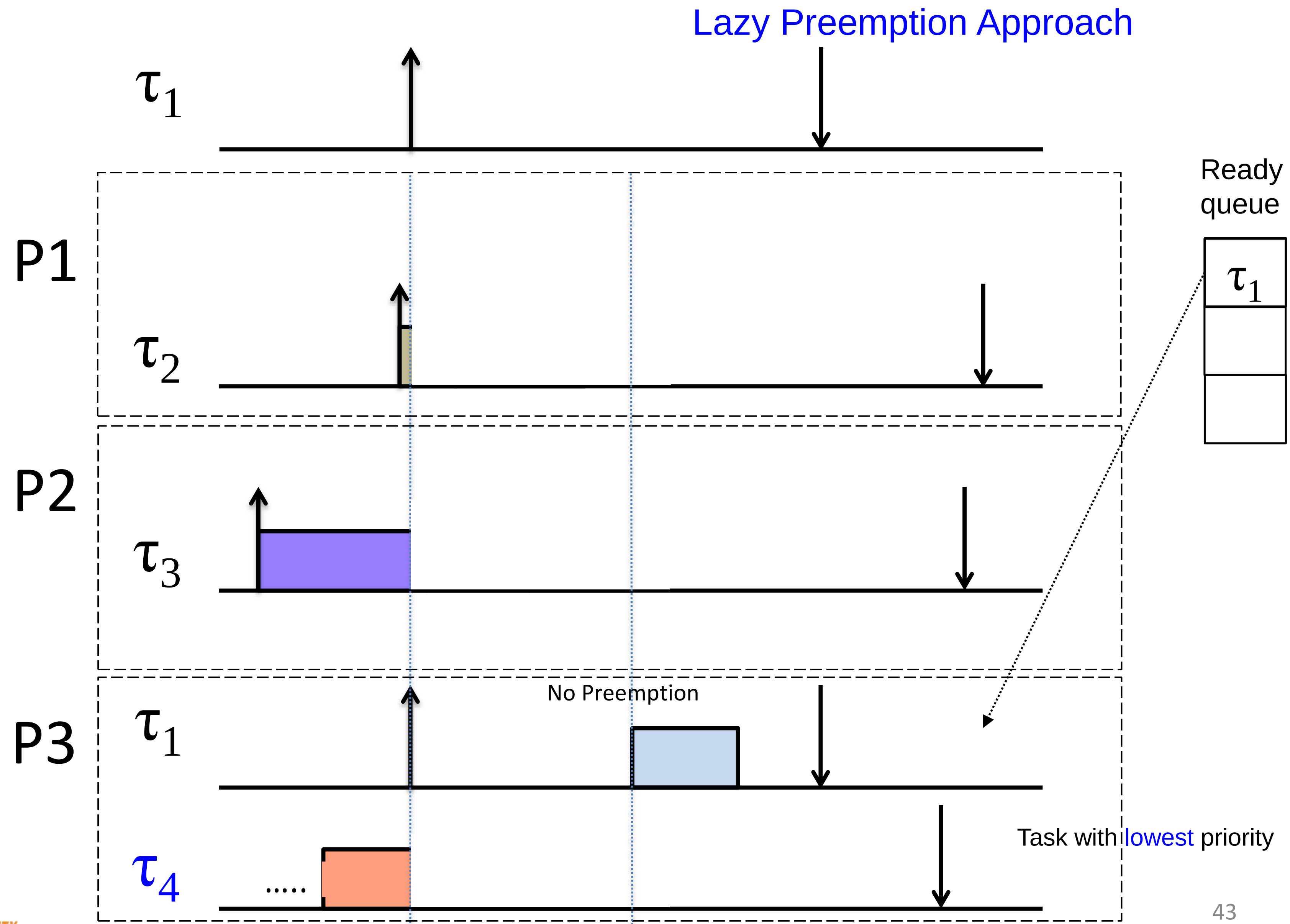
# Observations

1. Eager preemption approach generates most preemptions while lazy preemption approach generates least

2. Preemptive EDF generates fewer preemptions than preemptive FPS

3. Limited preemptive EDF generates more preemptions that limited preemptive FPS

# Preemptive Behavior under FPS

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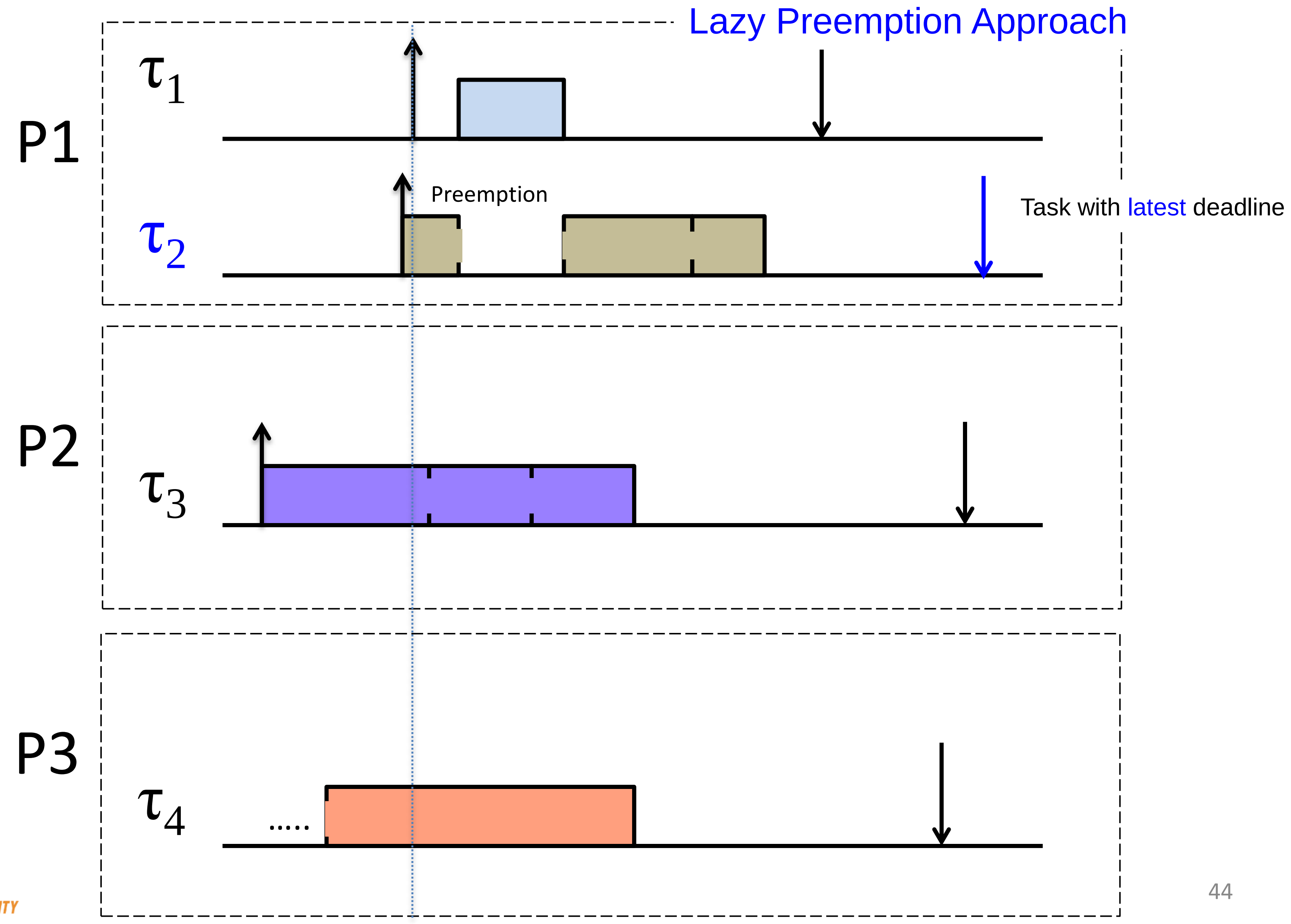
# Preemptive Behavior under EDF



# Conclusions

1. Limited preemptive scheduling on multiprocessors may not reduce the number of preemptions
   - Number of preemptions larger than fully preemptive scheduling under the eager approach
2. The preemptive behavior of EDF on uniprocessors generalizes to multiprocessors
   - G-P-EDF generates fewer preemptions than G-P-FPS
3. This, however, does not generalize to global limited preemptive scheduling
   - G-LP-EDF generates more preemptions than G-LP-FPS
4. G-LP-FPS with LPA generates the least number of preemptions

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# Future Work

- Hybrid approach to manage preemptions on multicores to get best of eager and lazy approaches: integration with preemption thresholds
- Probabilistic schedulability analysis for mixed-criticality tasks with fixed preemption points
- Improved preemption overhead accounting for tasks with fixed preemption points

# Thank you !

# Questions/Comments ?

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