Conditionally Optimal Task Parallelization for Global EDF on Multi-core Systems

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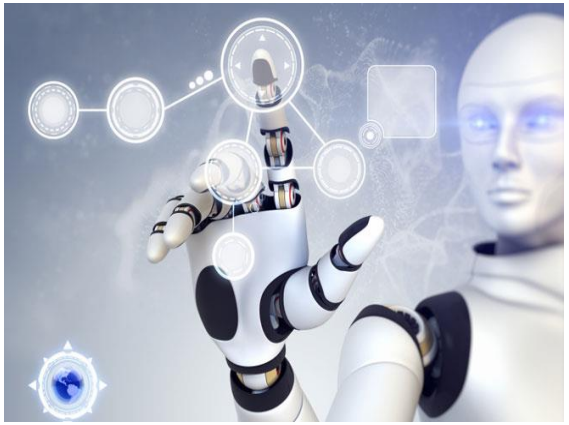
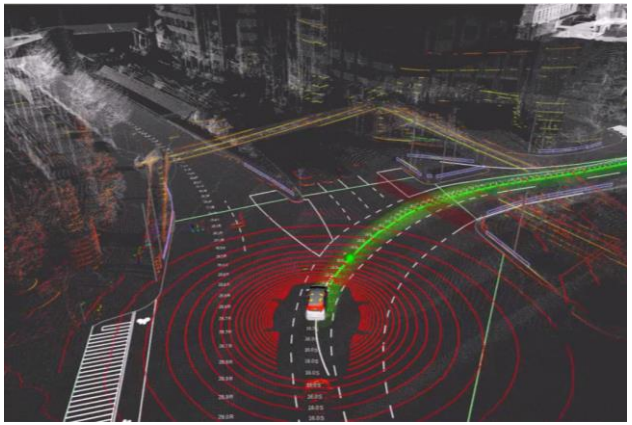
Overview

- Complex computations and massive data processing





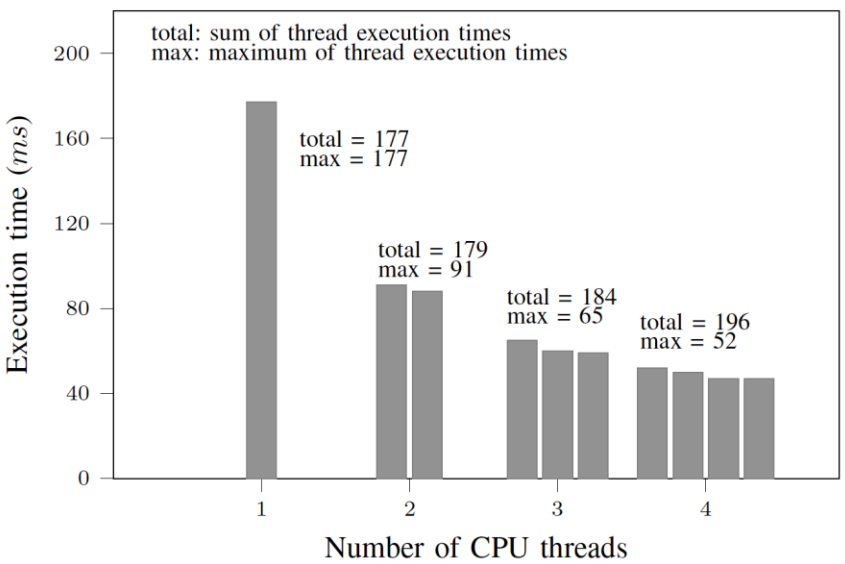
[img] http://blog.atmel.com/drone-leaders-form-small-uav-coalition/
[img] http://news.discovery.com/tech/robotics/intelligent-robots-overtake-humans-2100-130508.htm
[img] https://medium.com/@Engin_Bozkurt/a-general-overview-and-comparison-of-autonomous-driving-visualization-and-test-frameworks-cb182147a907

Overview (2)

- Parallelization freedom
  - multiple runtime versions

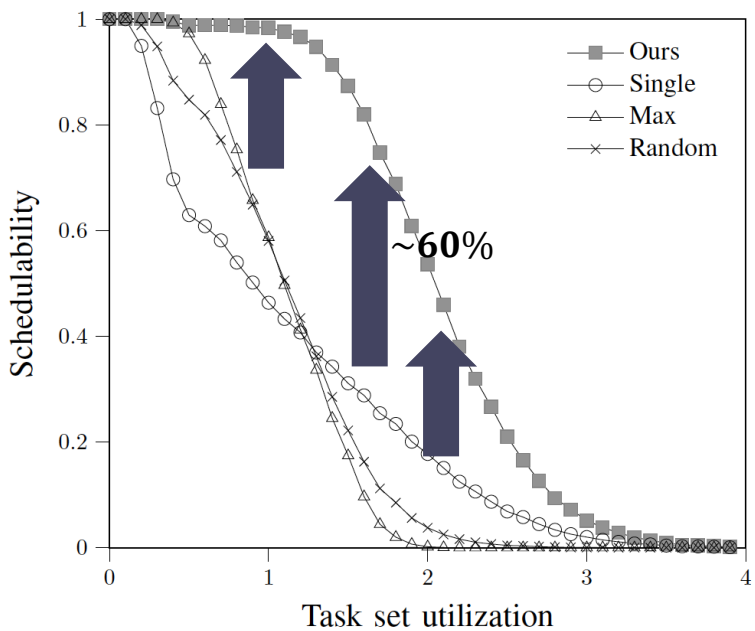
OpenCL

OpenMP



Measured thread execution times of a lane tracking program

- <u>Our Contribution</u>
  - ✓ Optimal algorithm
  - ✓ Polynomial time complexity
  - ✓ Significant schedulability improvement



Motivation

- Example – Autonomous Driving

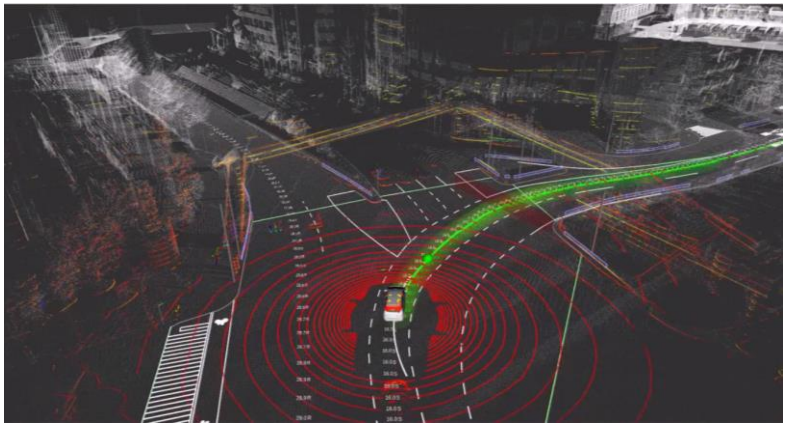
τ_1: Sensor read/process

τ_2: Lane Tracking

τ_3: Object detection/labeling

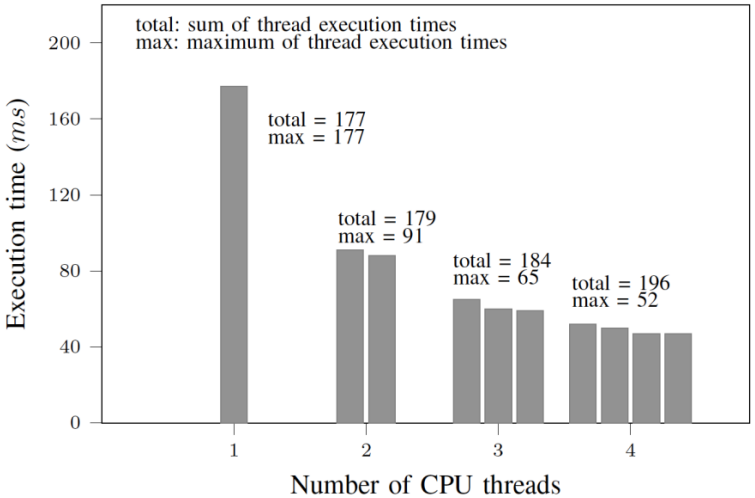
τ_4: Steering actuation

…



- Parallelization Options

$Parallelize$



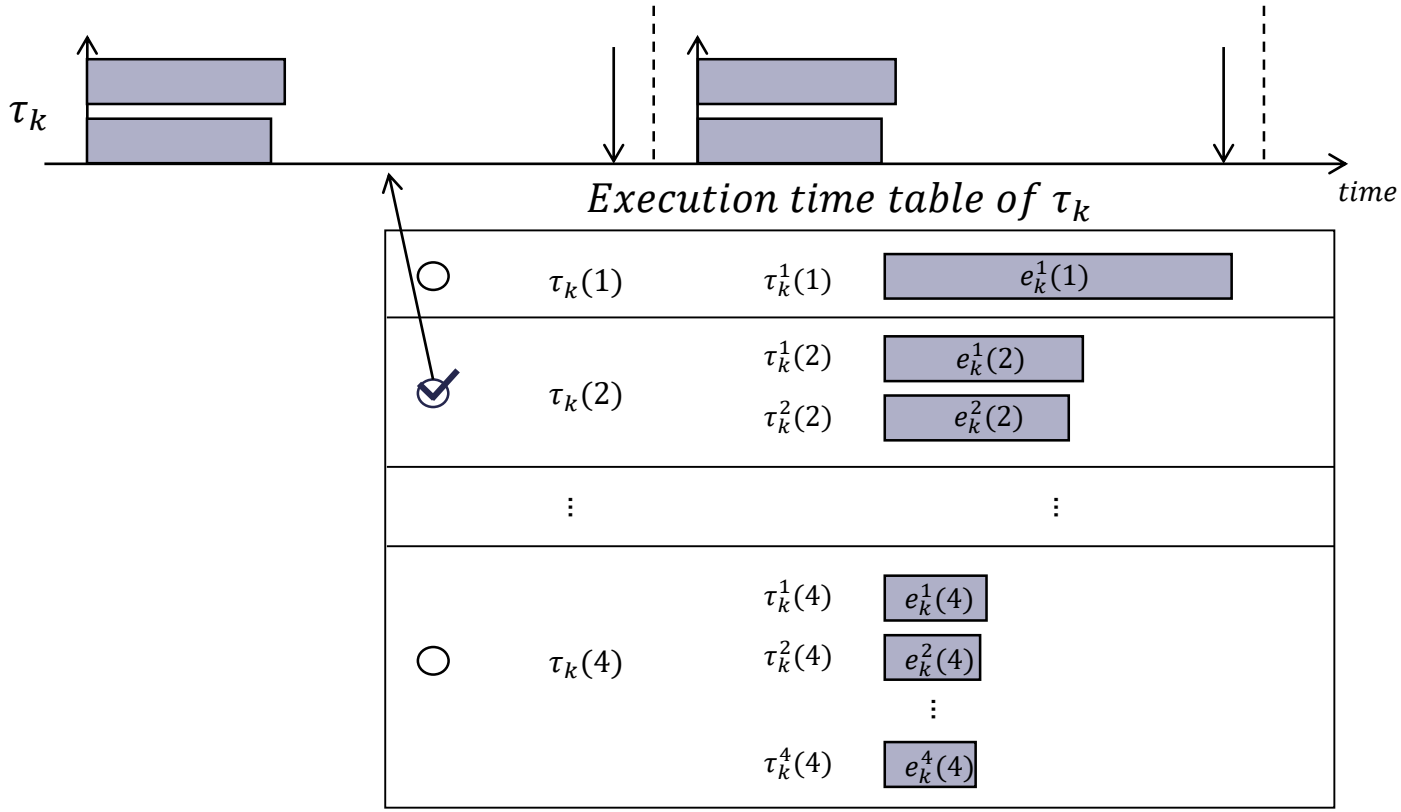
Different multi-thread versions
by OpenCL/OpenMP

[img] https://medium.com/@Engin_Bozkurt/a-general-overview-and-comparison-of-autonomous-driving-visualization-and-test-frameworks-cb182147a907

Our Problem

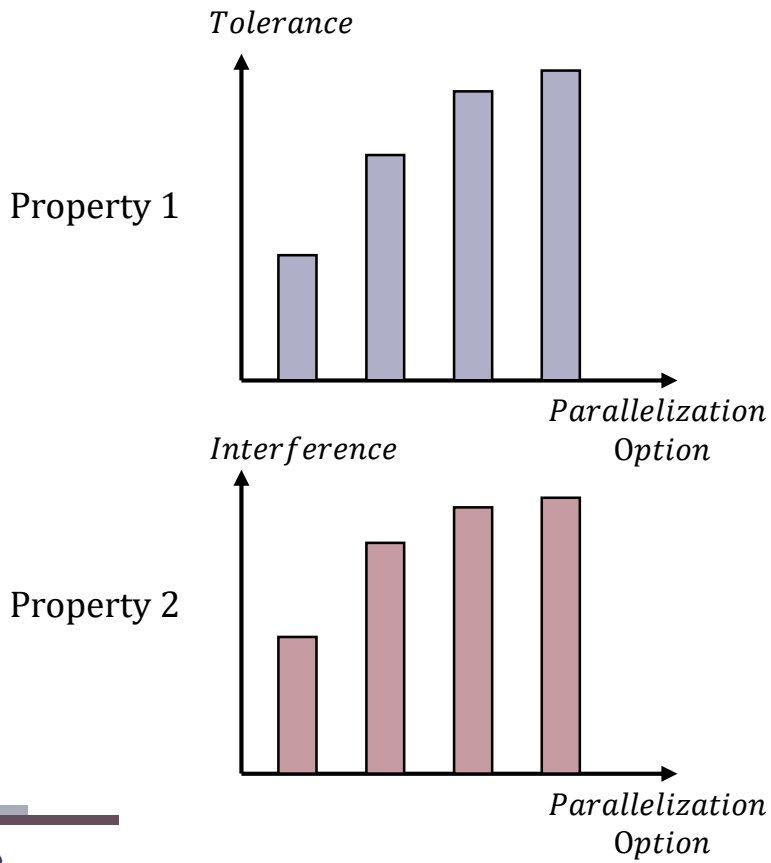
- n sporadic tasks with parallelization freedom, m CPU cores

→ Assign optimal parallelization option to each task to maximize schedulability

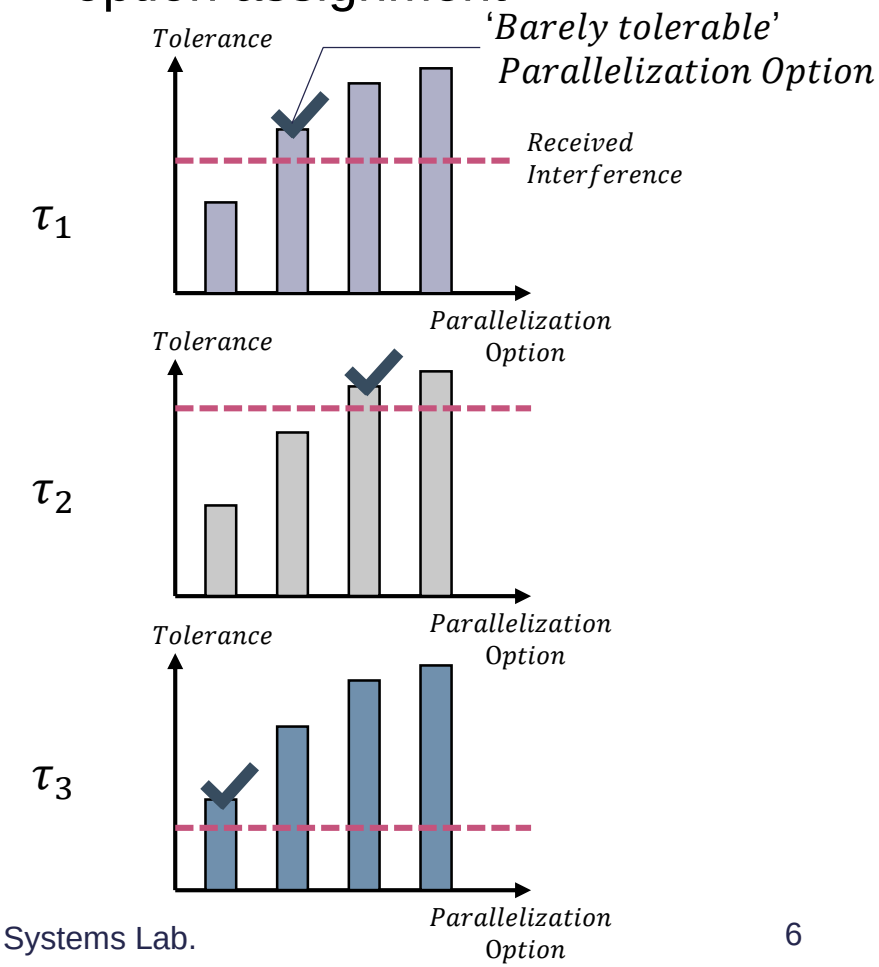


Solution Approach

- Monotonic increasing property of both tolerance and interference

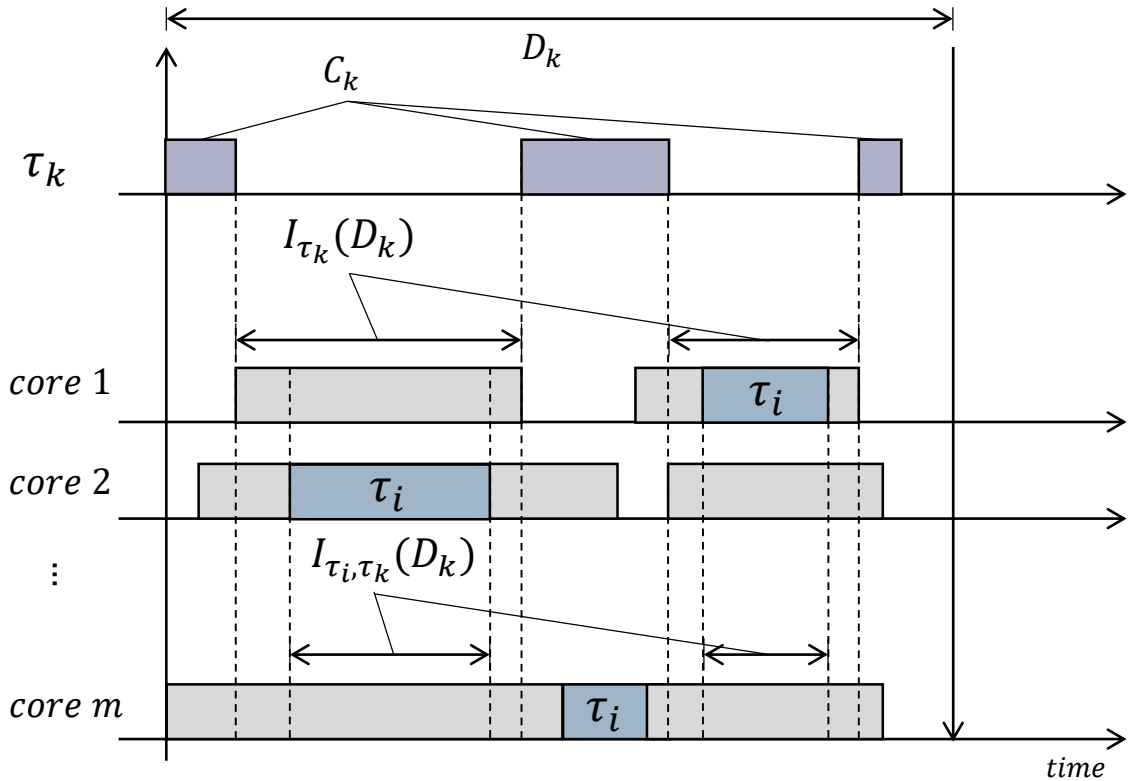


- Optimal parallelization option assignment



Interference-Based Schedulability Analysis

- Execution of a task of interest:
- … can be interfered by other tasks:



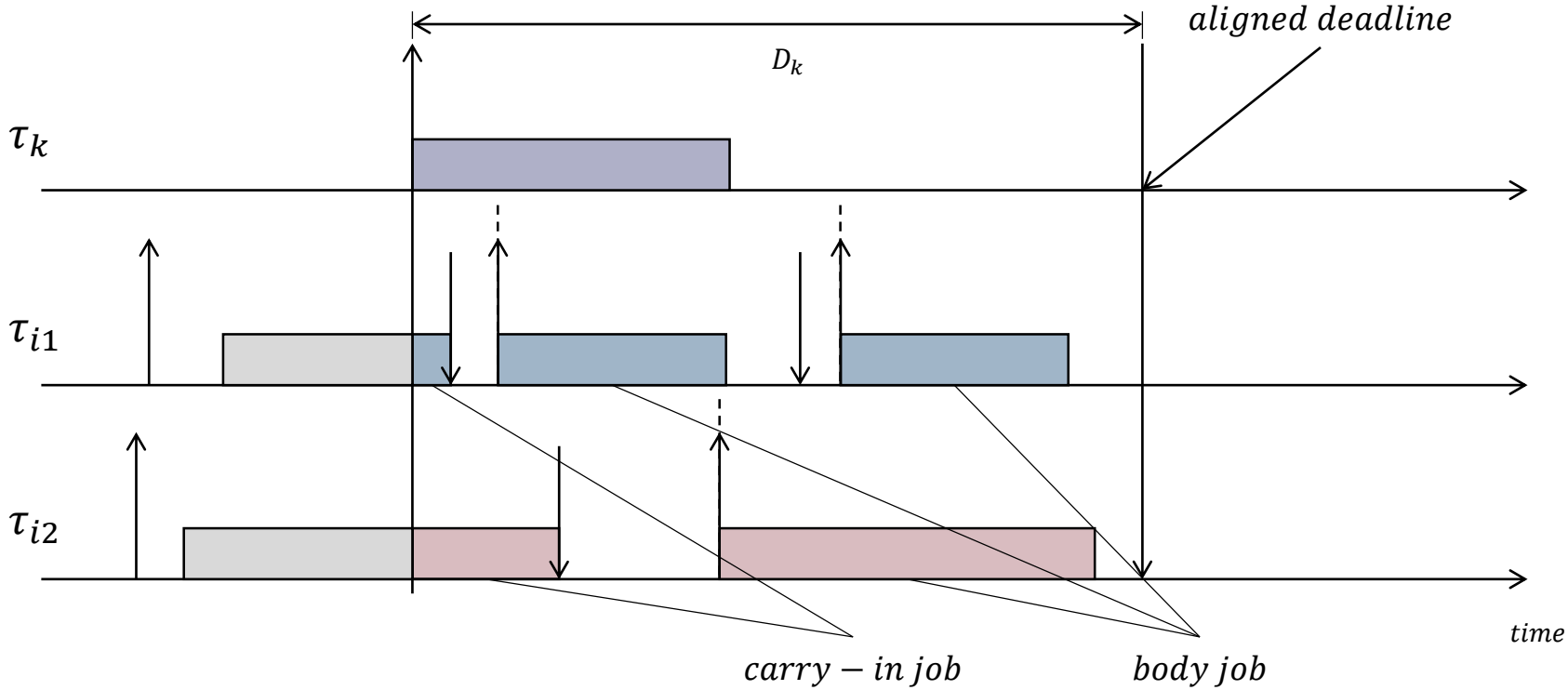
- Scheduling Condition†:

$$\underbrace{I_{\tau_k}(D_k) = \frac{1}{m}\sum_{\tau_i \neq \tau_k} I_{\tau_i,\tau_k}(D_k)}_{\substack{sum\ of\ interference \\ from\ other\ tasks}} \leq \underbrace{D_k - C_k}_{\substack{task's \\ tolerance}}$$

† M. Bertogna, M. Cirinei, and G. Lipari, “Improved schedulability analysis of edf on multiprocessor platforms,” ECRTS, 2005

Worst-Case Workload in G-EDF

- Interference is bound by total workload†:

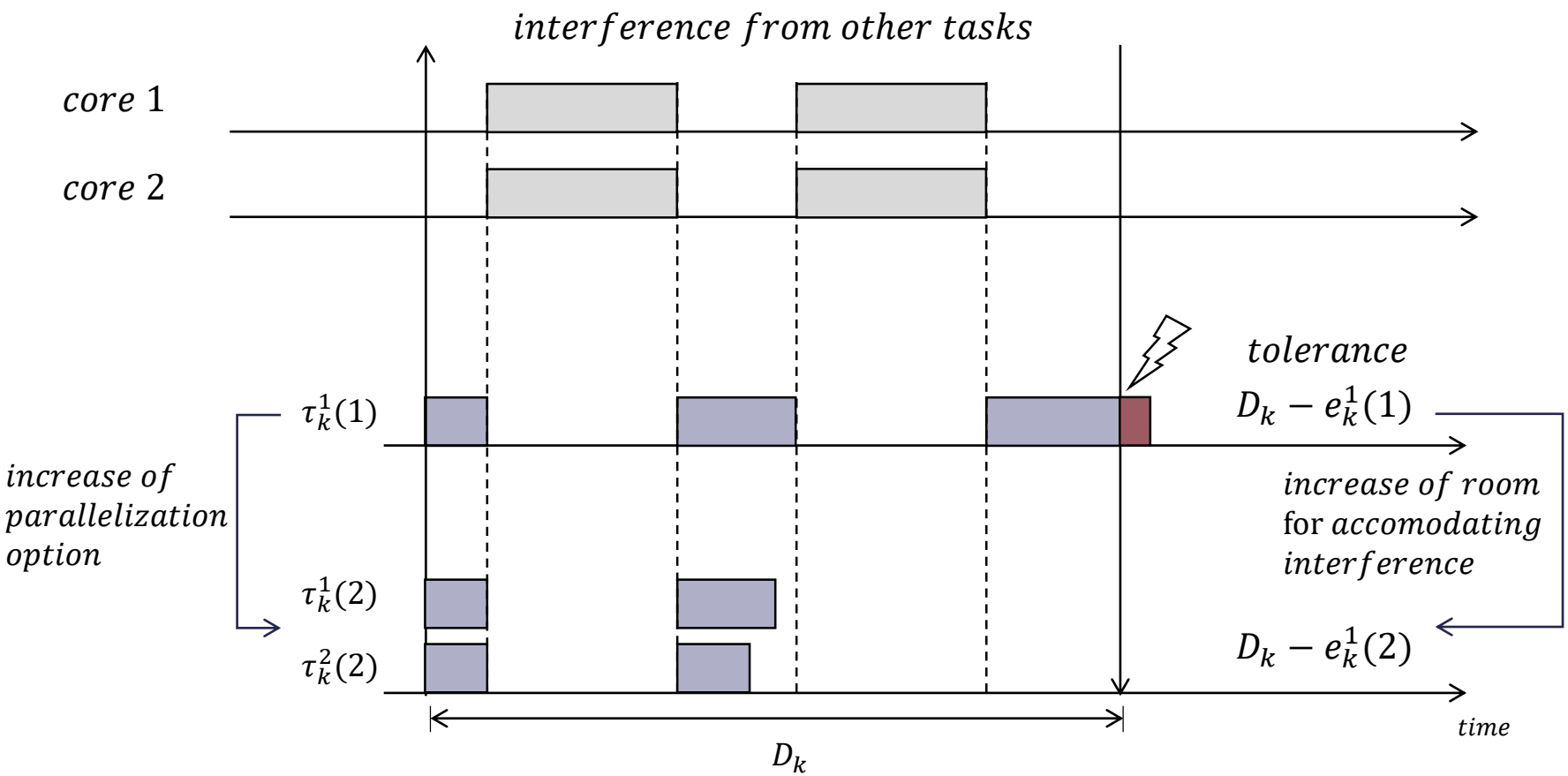


$$\frac{1}{m}\sum_{\tau_i \neq \tau_k} I_{\tau_i,\tau_k}(D_k) \leq \frac{1}{m}\sum_{\tau_i \neq \tau_k}\left(\boxed{\min(C_i, D_k \bmod T_i)} + \boxed{\left\lfloor \frac{D_k}{T_i} \right\rfloor C_i} \right) \leq D_k - C_k$$

† M. Bertogna, M. Cirinei, and G. Lipari, “Improved schedulability analysis of edf on multiprocessor platforms,” ECRTS, 2005

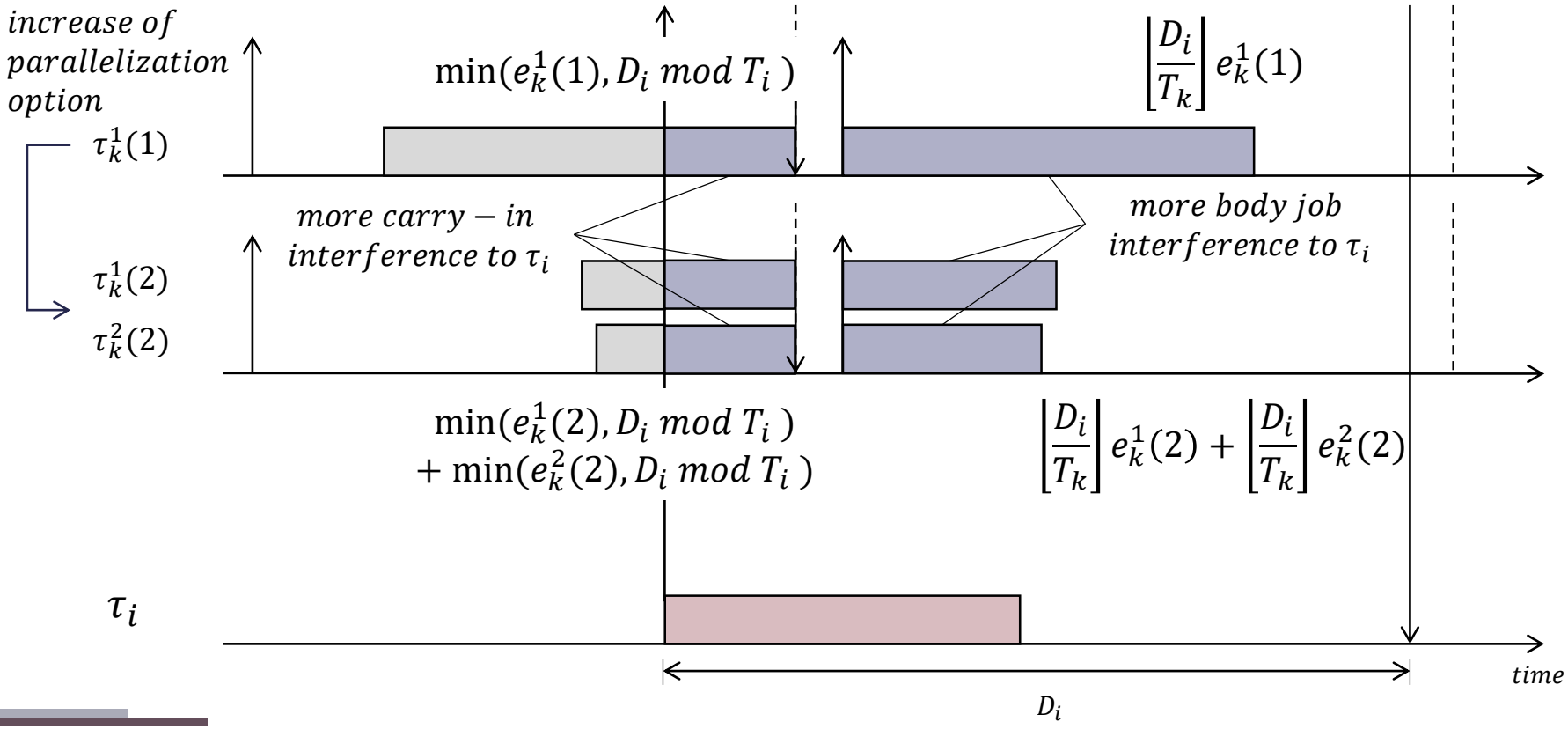
Property 1

- Monotonic increasing property of tolerance of τ_k.



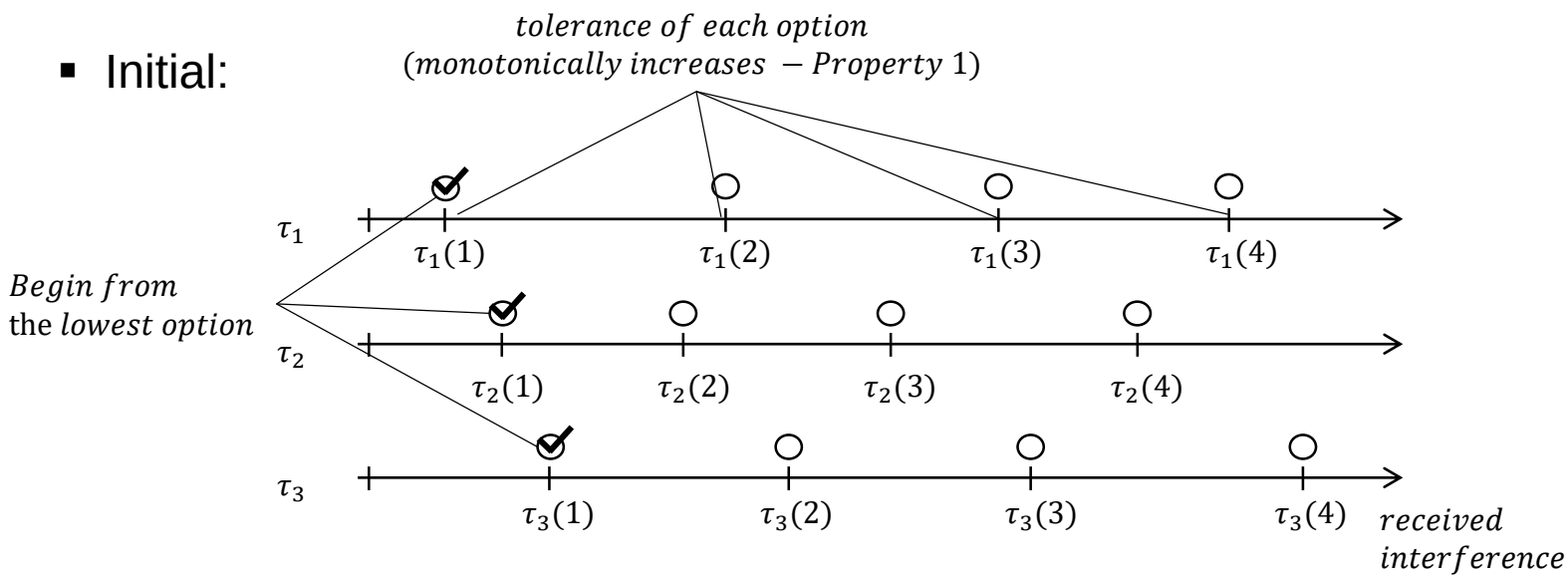
Property 2

- Monotonic increasing property of interference given by τ_k to another task τ_i.



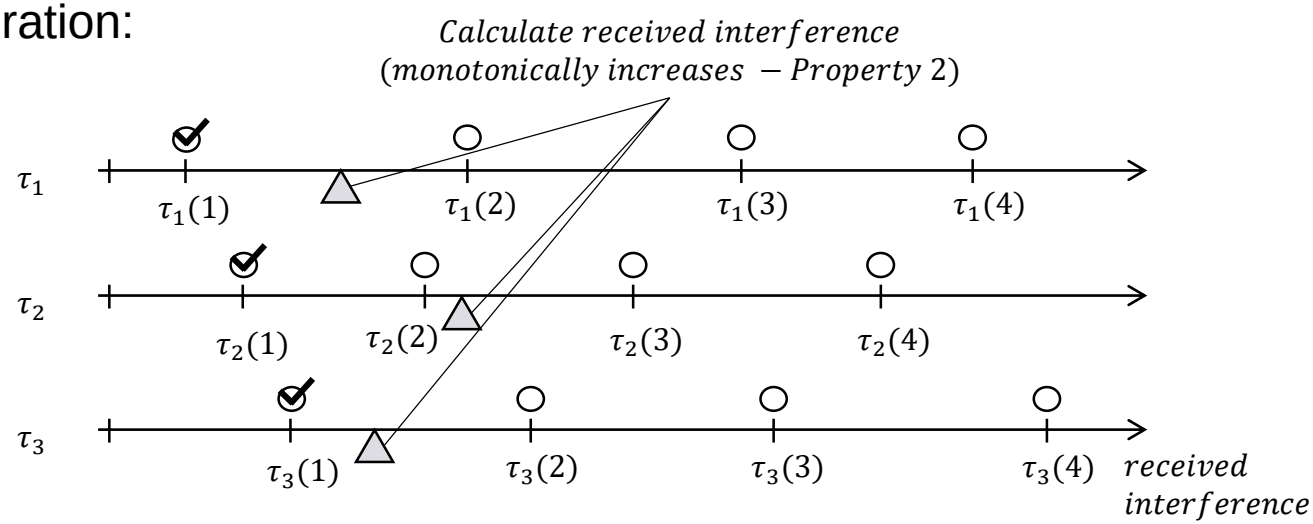
Optimal Parallelization Option Assignment

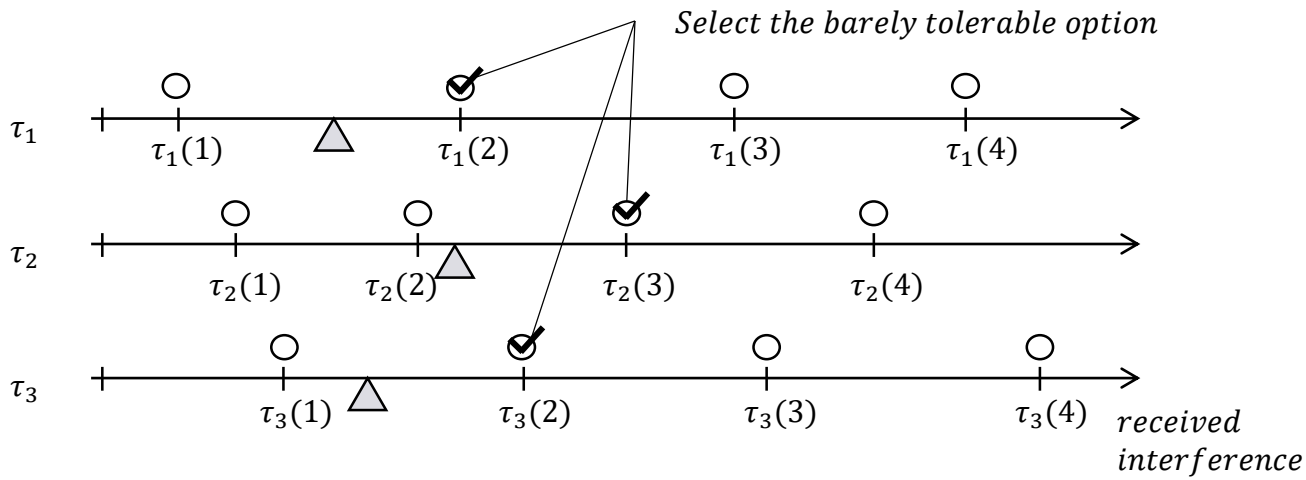
- Begin from the lowest parallel option.
- For all tasks, iteratively,
  1. Calculate the interference from other tasks.
  2. Raise parallelization option to the ‘barely tolerable’ option.
- Initial:



Optimal Parallelization Option Assignment (2)

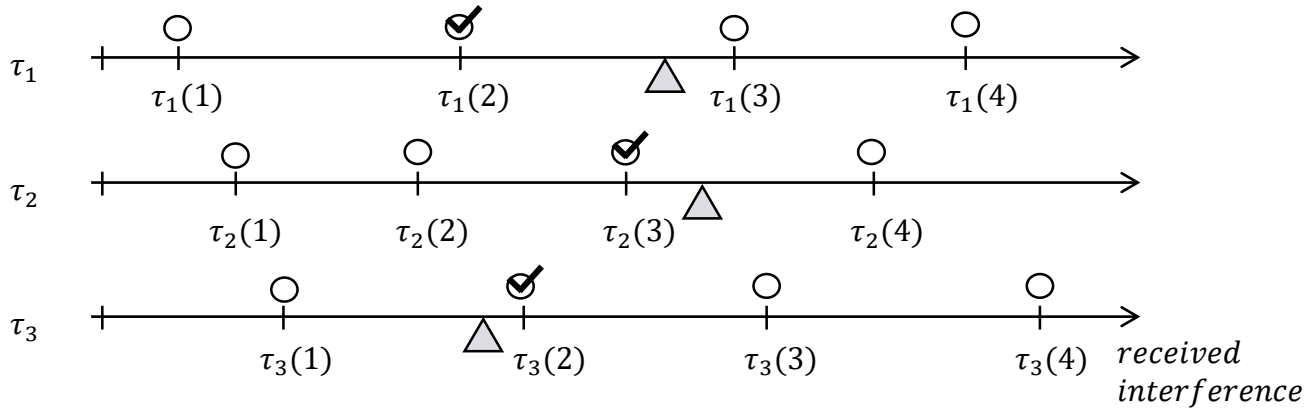
- First iteration:

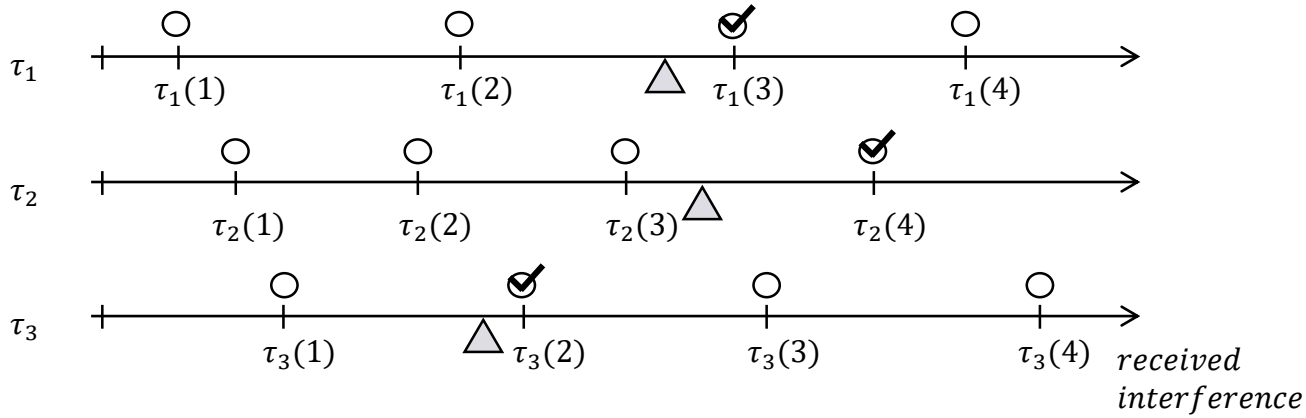




Optimal Parallelization Option Assignment (3)

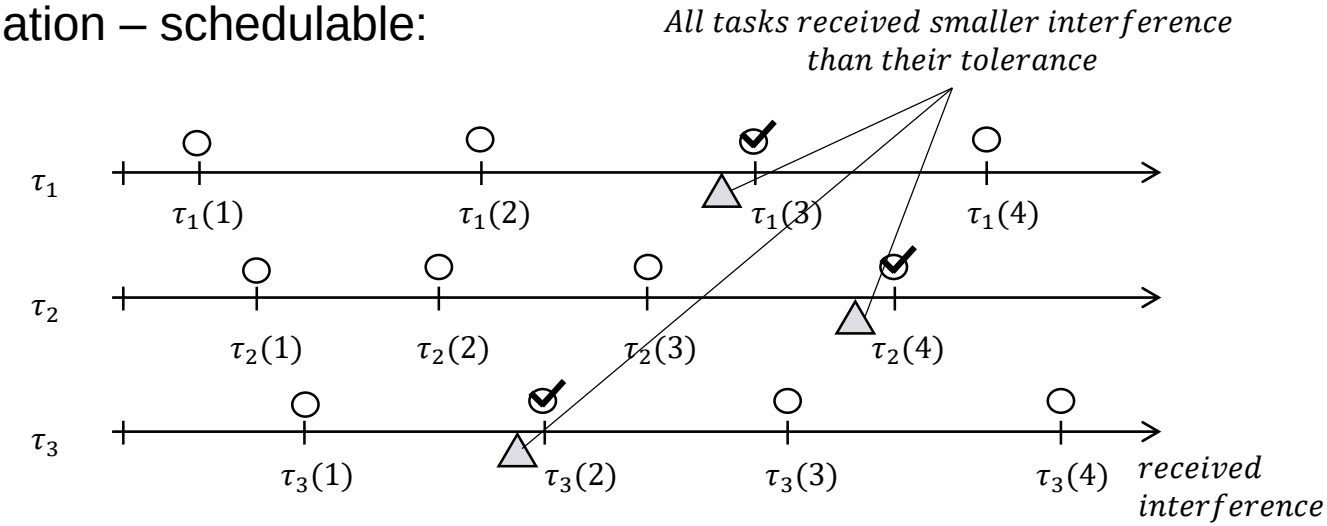
- Second iteration:



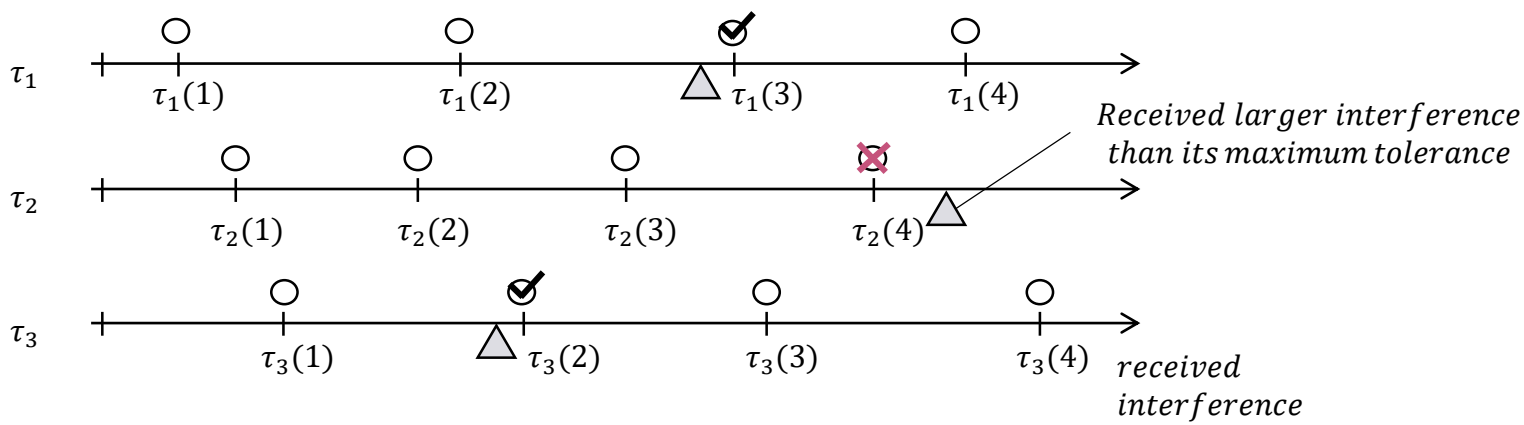


Optimal Parallelization Option Assignment (4)

- Termination – schedulable:

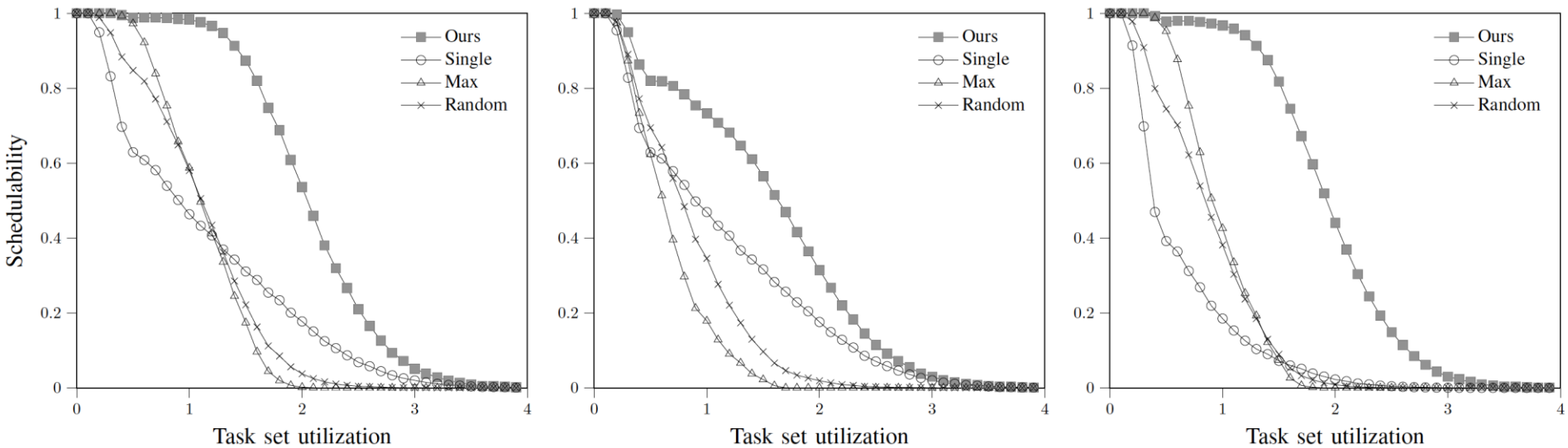


- Termination – not schedulable:



Simulation Results

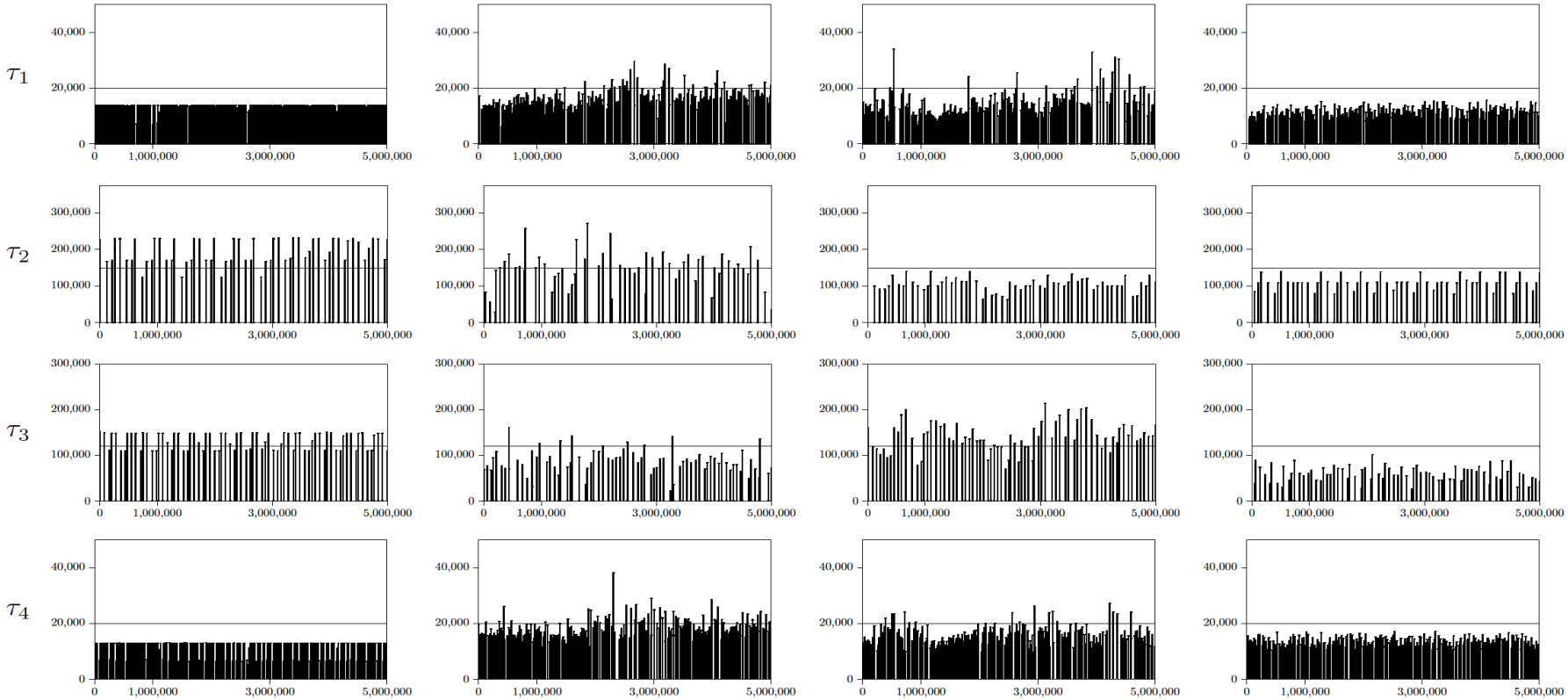
- Normalized task set schedulability vs. task set utilization ($\sum {}^{C_i}/_{T_i}$).
- 10^6 synthesized tasks scheduled on $m = 4$ CPU cores.



(a) *Base* (b) *High parallelization overhead* (c) *Tight deadline*

Implementation Results

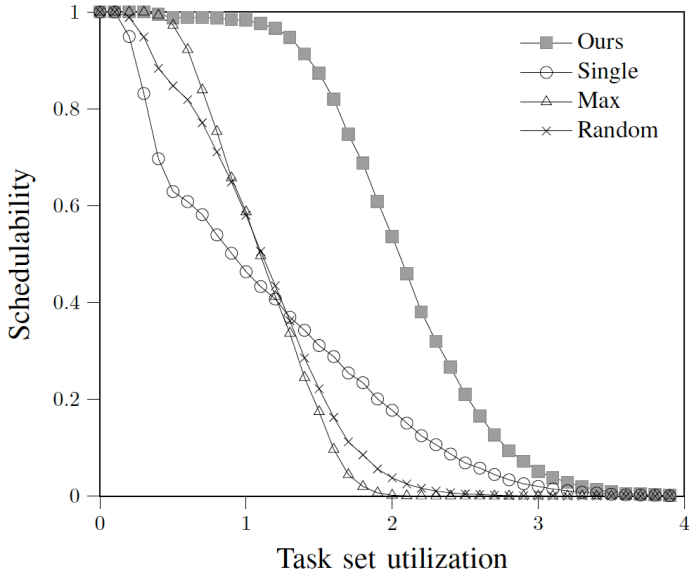
- Measured response times(μs) of autonomous driving tasks on 4 CPU cores.
- (τ_1: sensor, τ_2: lane track, τ_3: object detection, τ_4: motor).



(a) *Single* (b) *Max* (c) *Random* (d) *Ours*

Conclusion

- Optimal parallelization option assignment for global EDF
- Polynomial time complexity
- Significant schedulability improvement



- Future work: Extension towards…
  - Different state-of-the-art schedulability analyses
  - Multi-segment/DAG task model

Thank You

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