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Techniques Optimizing the Number of Processors to Schedule Multi-Threaded Tasks

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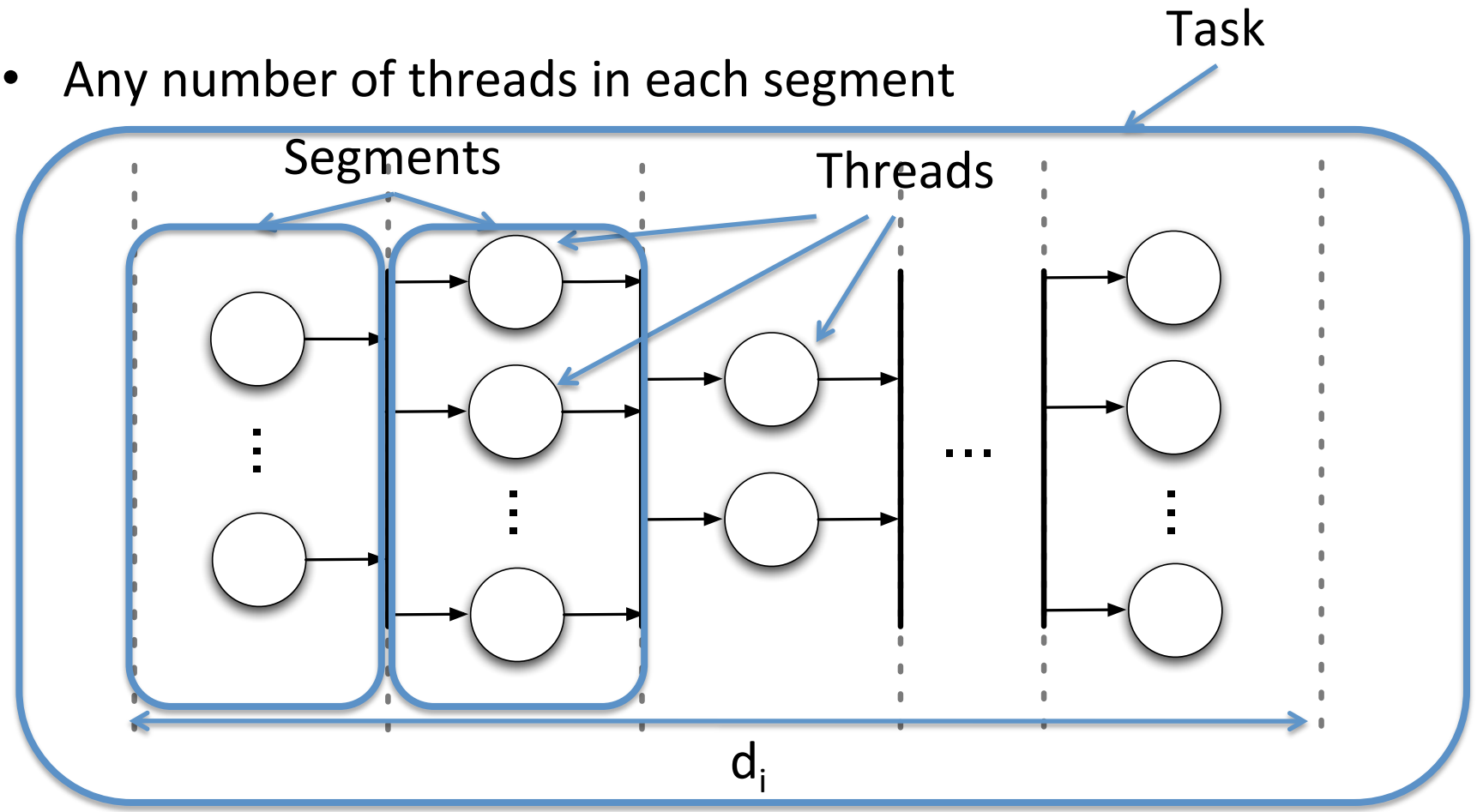
Multiprocessor platforms purpose: Parallelization

- What can we parallelize?
  - Traditional approach: execution of many **sequential** tasks
    - But… #CPU is increasing -> Systems with more CPUs than tasks
  - New approach: execution of **parallel tasks**
    - Solid background for parallelization in the "non-real time" world
    - Explicit parallel coding : MPI, PVM, OpenMP, multi-thread
    - Compiler (automatic) parallelization
- Should we develop two different scheduling models?
- If not: How could we efficiently use the existing theory?

Generalization of the Fork-Join model

- Any number of threads in each segment

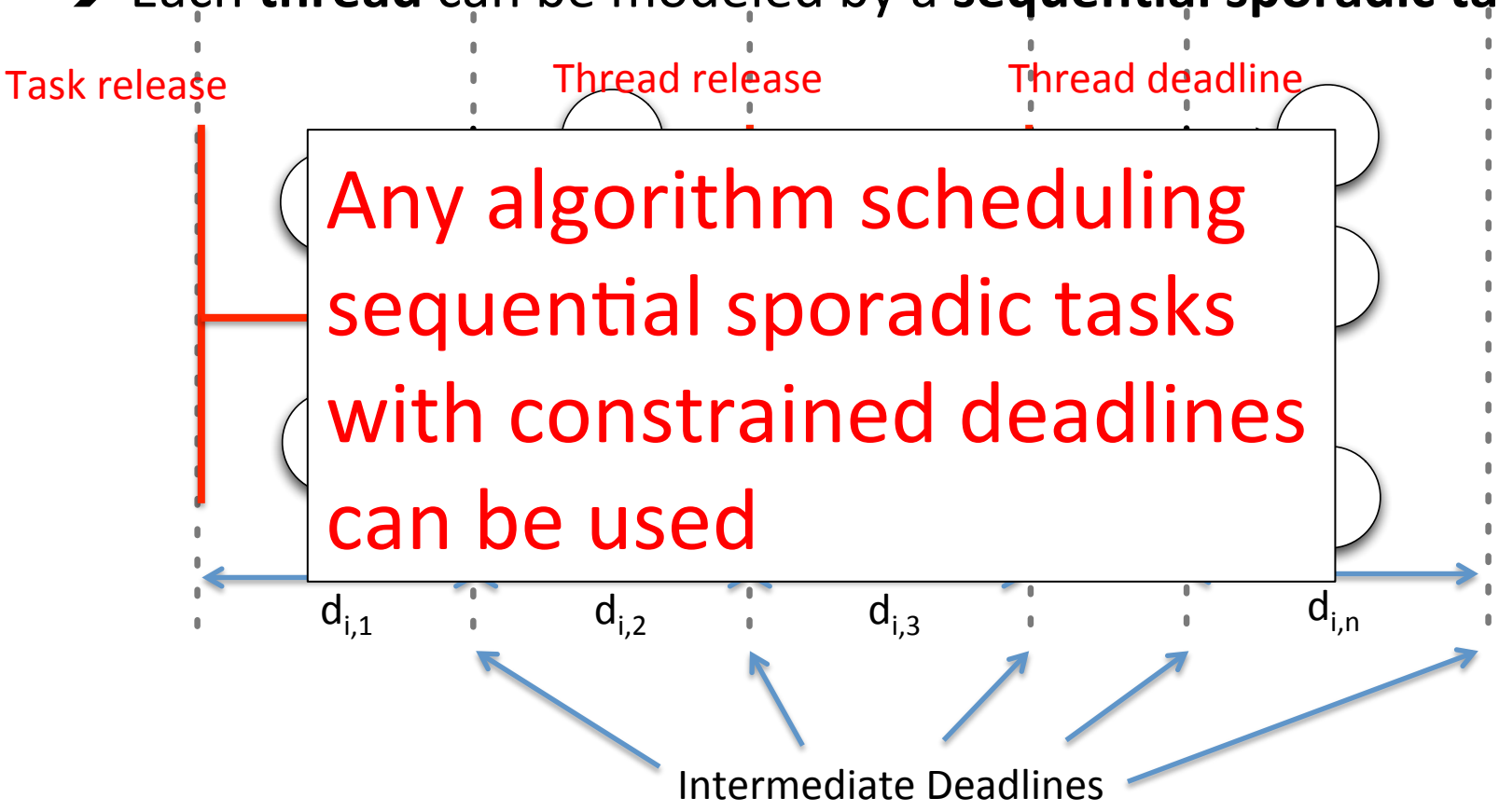


- **Sporadic** multi-threaded tasks with **constrained deadlines**

How could we use the existing scheduling theory with such a model?

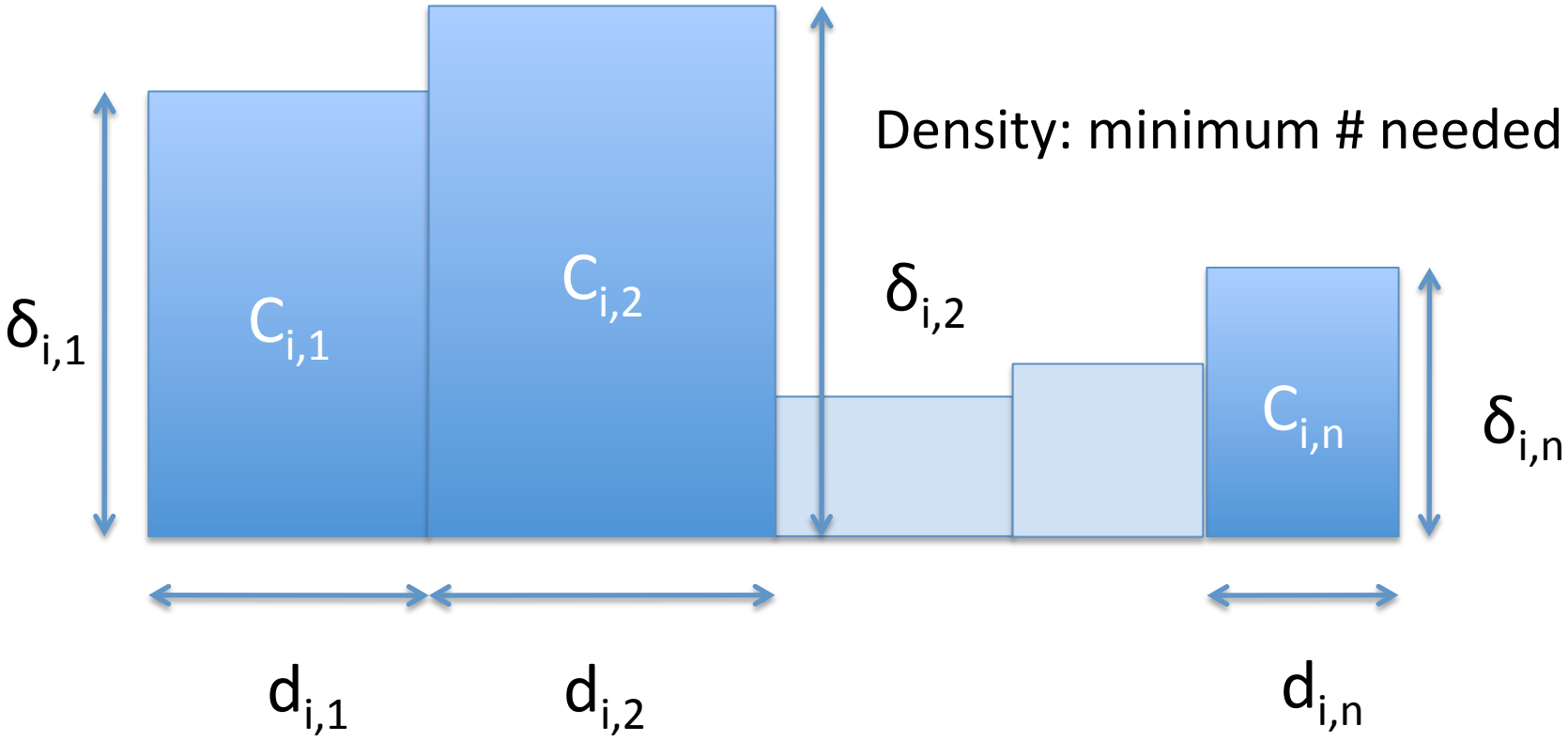
- Adding artificial intermediate deadlines

➔ Each **thread** can be modeled by a **sequential sporadic task**

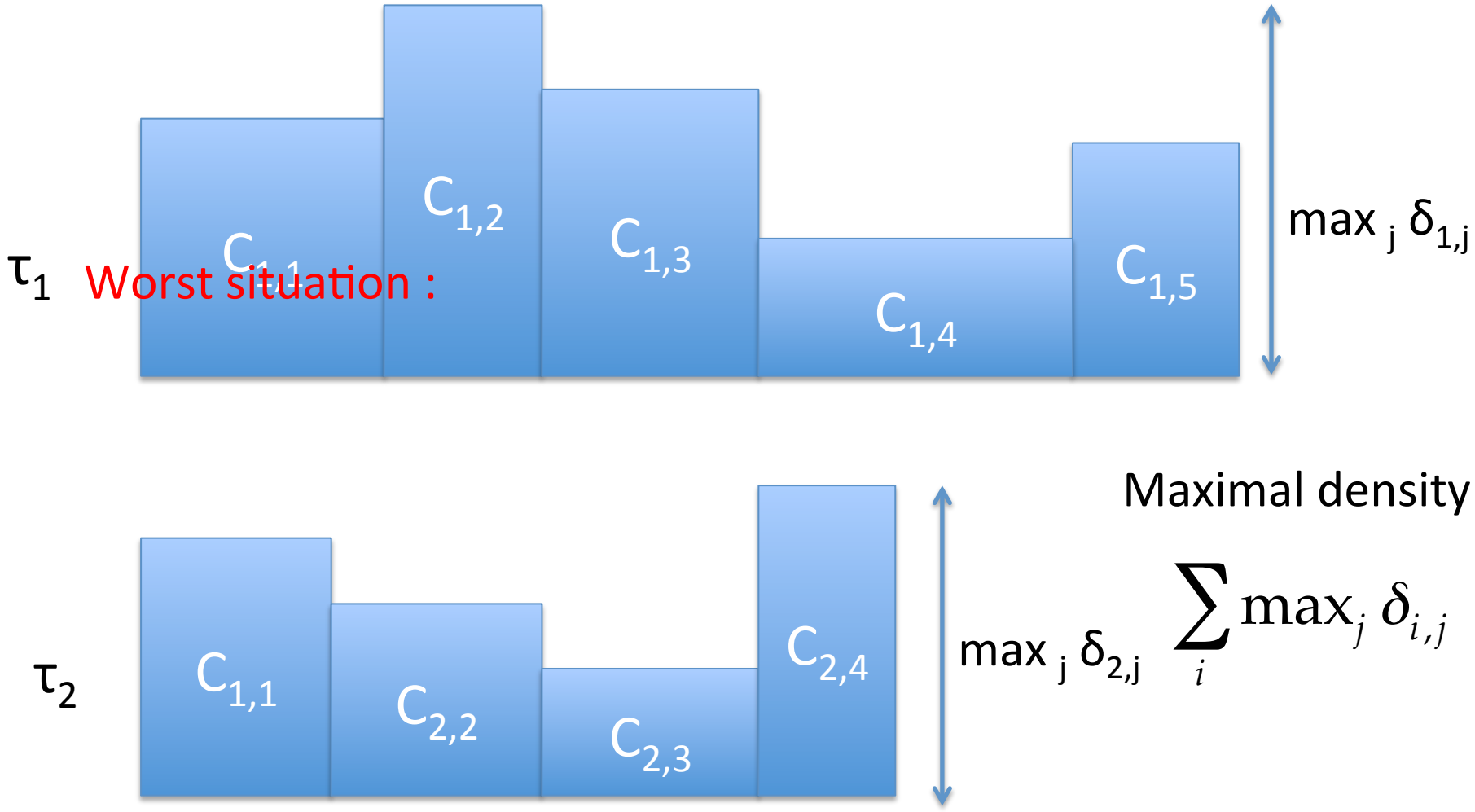


Density of a segment

Density of a segment $\tau_{i,j}$: $\delta_{i,j} = \frac{C_{i,j}}{d_{i,j}}$



Density of a task system



Maximal density :

$$\sum_i \max_j \delta_{i,j}$$

How do we minimize the number of processors?

- A sufficient schedulability test for PD^2, DP-Wrap, **U-EDF**:

$$m \geq \delta(t), \ \forall t$$

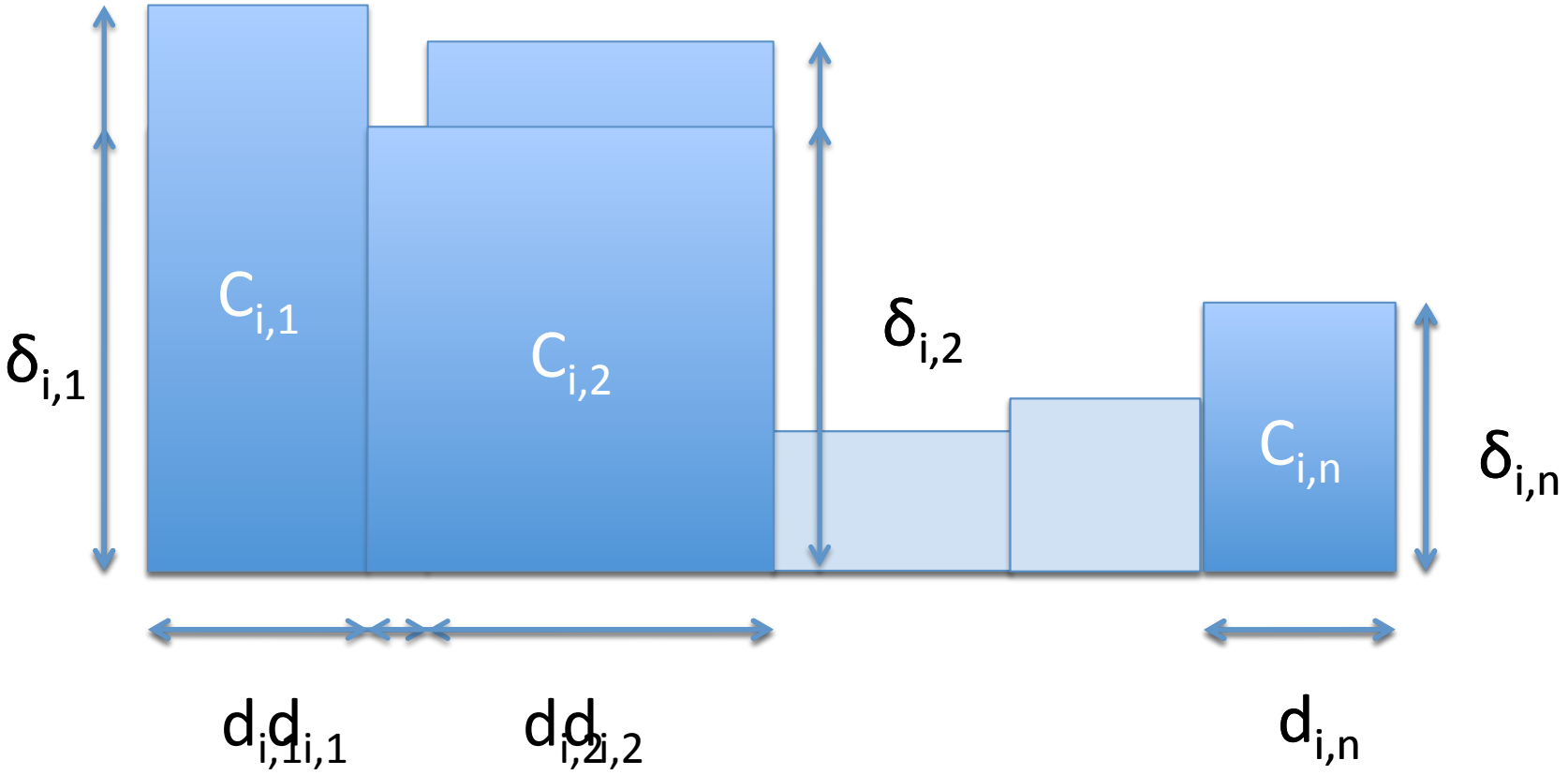
- Minimizing m ➔ minimizing the total maximal density

$$\sum_i \max_j \delta_{i,j} = \sum_i \max_j \frac{C_{i,j}}{d_{i,j}}$$

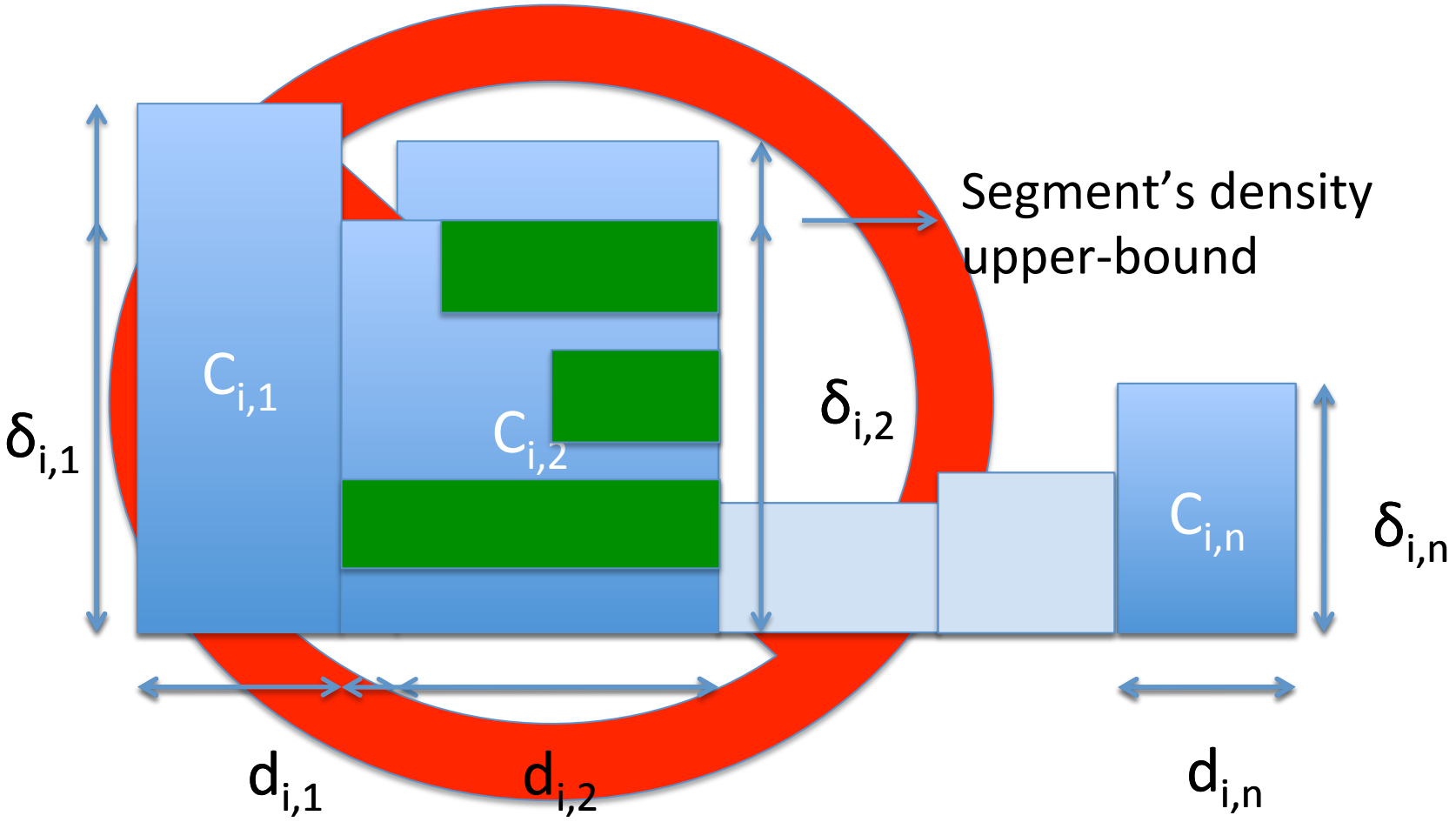
- Terms are independent ➔ minimizing the maximal density for each task

$$\max_j \frac{C_{i,j}}{d_{i,j}}$$

Density of a segment

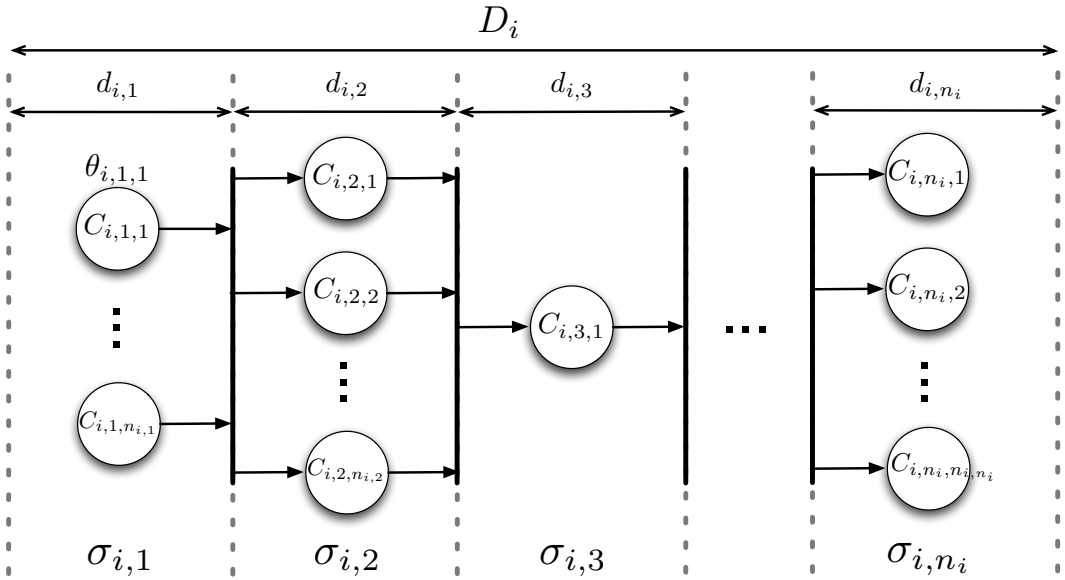


Density of a segment



This Problem can be expressed as a Linear Optimization Problem

- Minimize: Maximum density reachable by the segments
- Subject to:
  - Intermediate deadline ≥ Largest thread execution (for each segment)
  - Sum of intermediate deadlines ≤ Task deadline



Let us try to understand the optimal solution

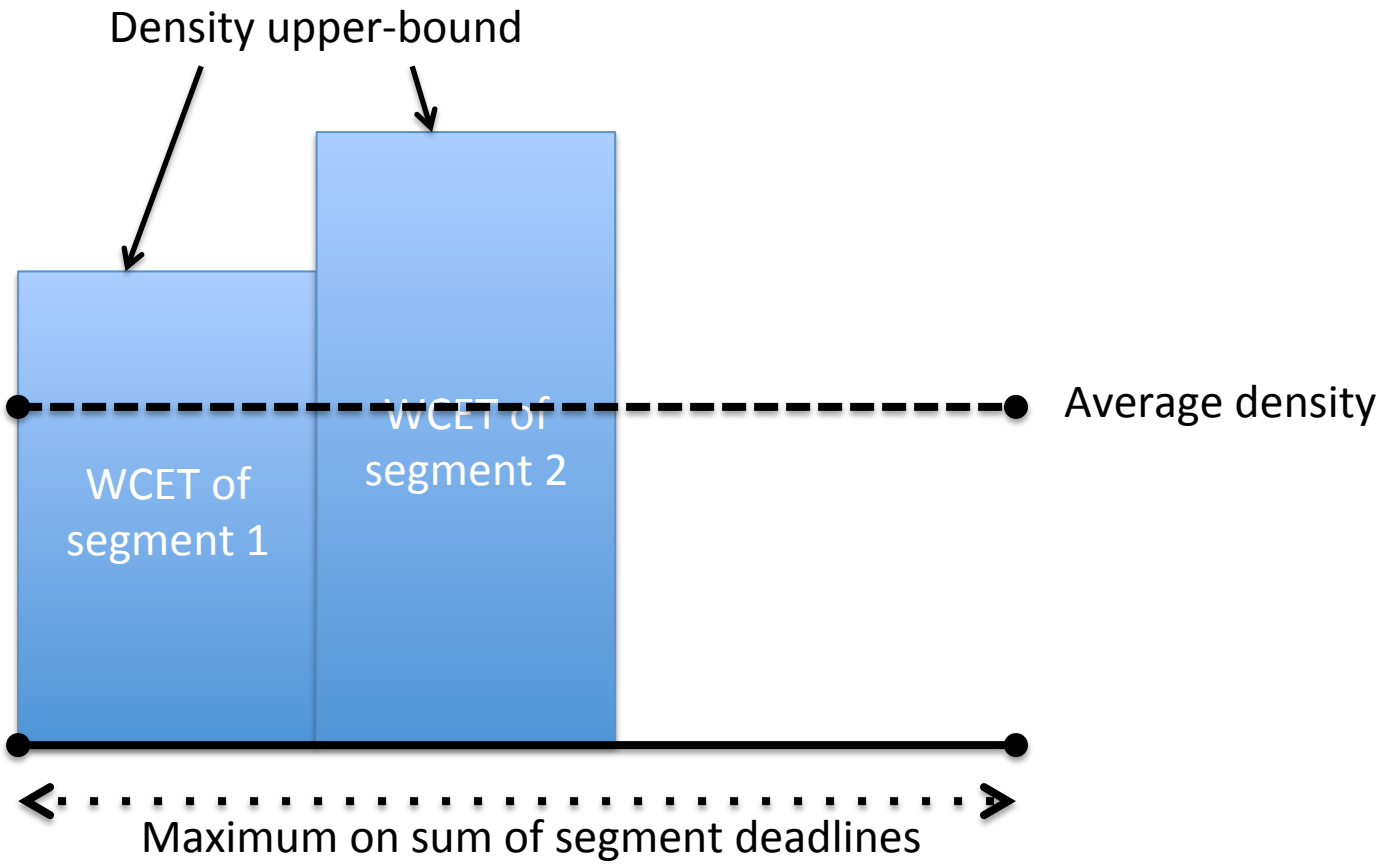
- The deadline of a segment cannot be smaller than the WCET of its threads

➔The segment density is upper-bounded

- An **optimal** solution can be found by **comparing** the **upper-bound of all segment densities** with the **average density** of the task

Let us try to understand the optimal solution

- **Rule 1:** Keep the density constant if possible



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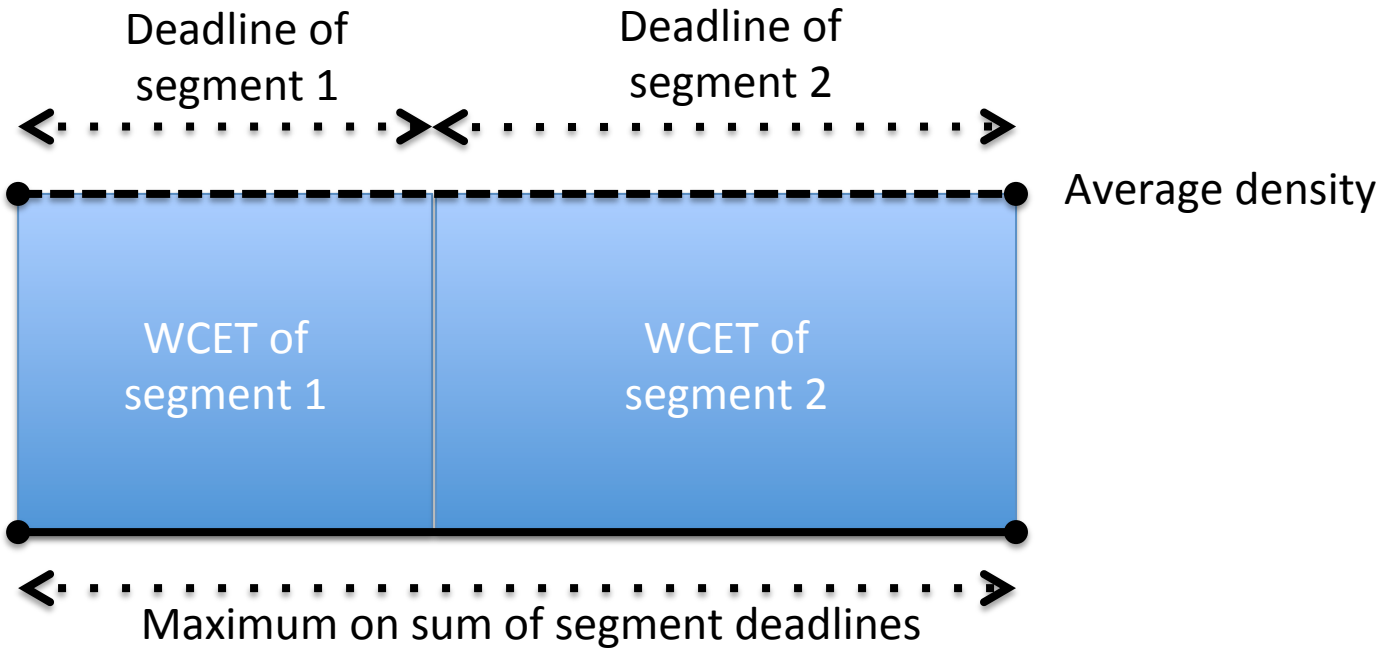

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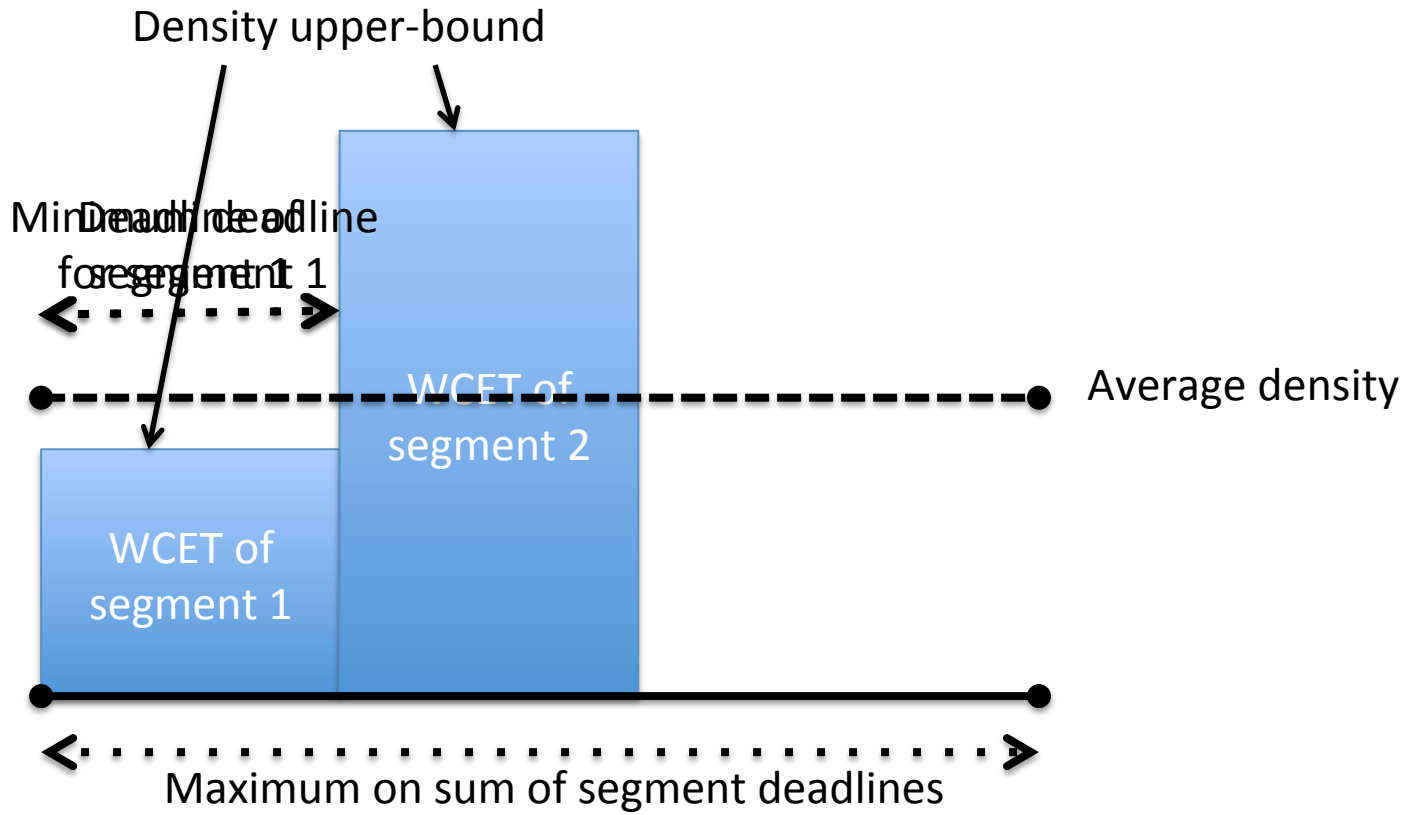
- **Rule 2:** Minimize impact of segments with small densities



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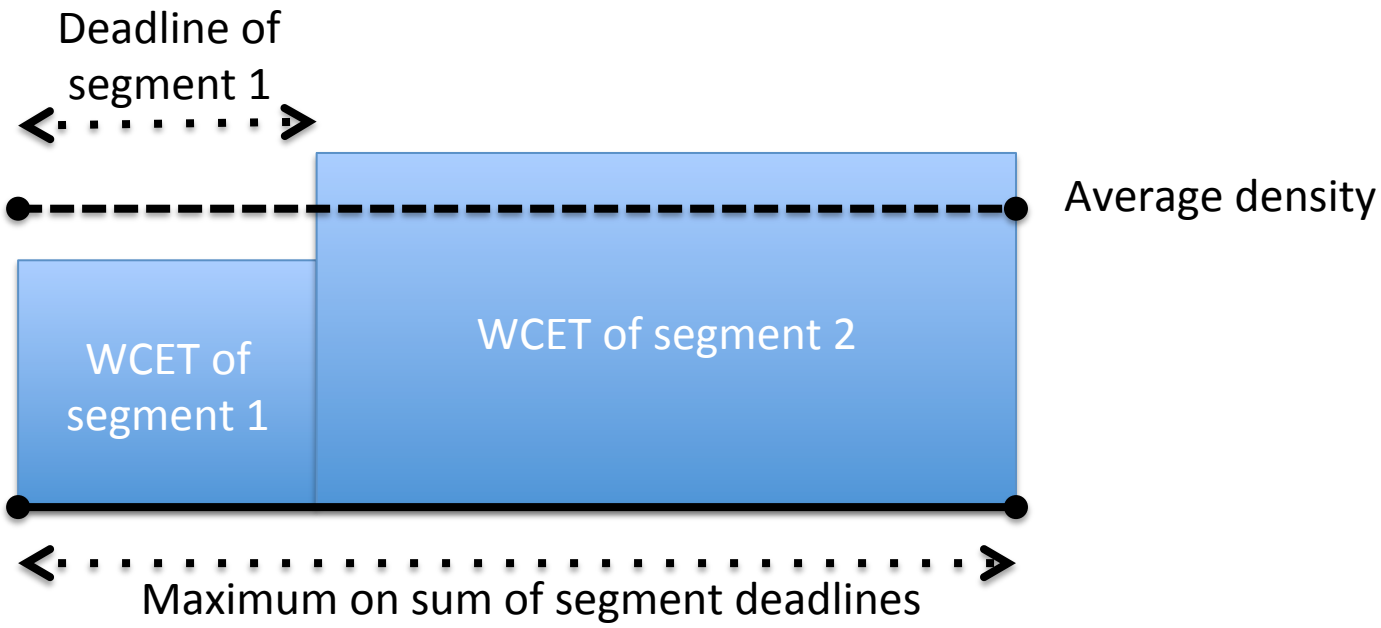
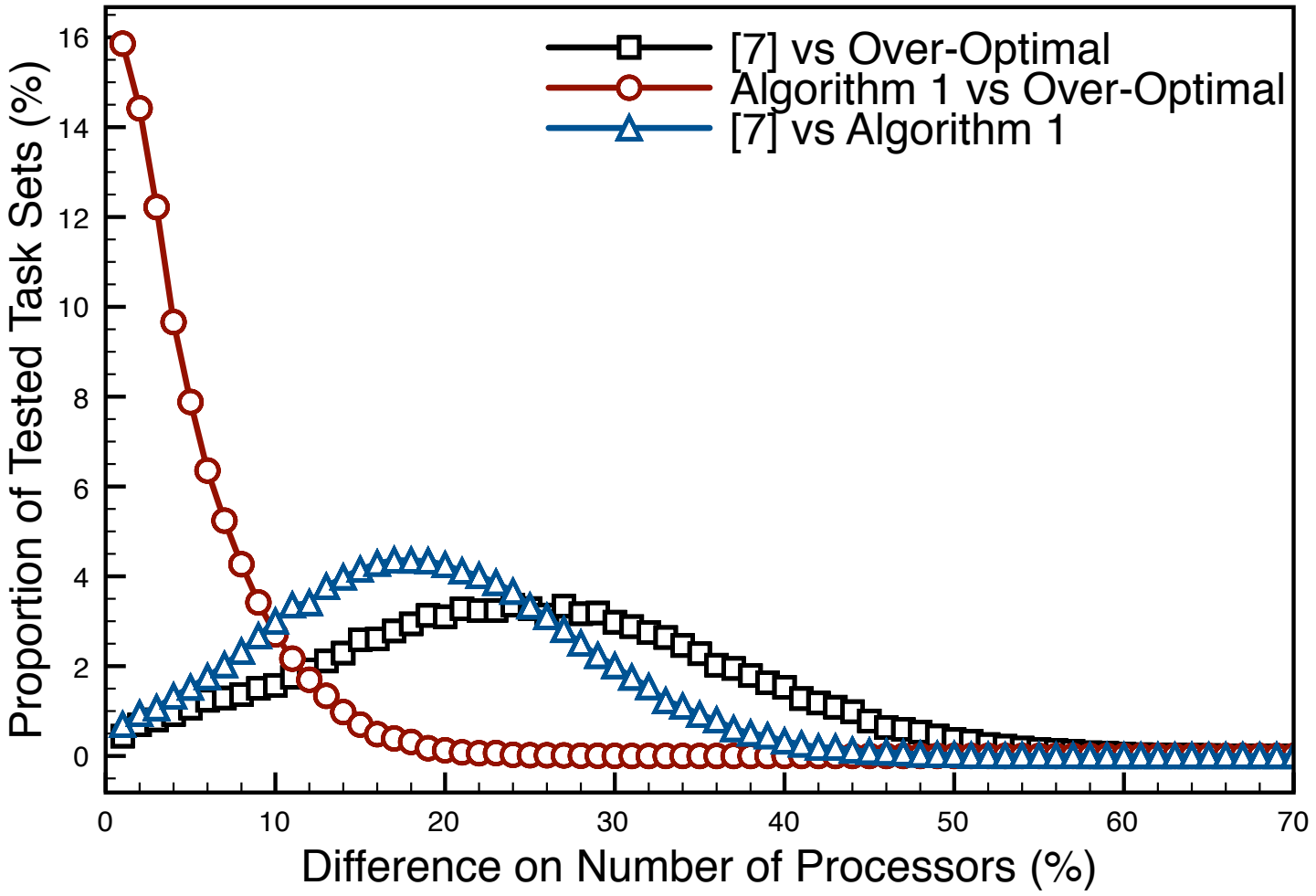


A simple algorithm to find an optimal solution

- Sort segments by their density upper-bounds
- **For each** segment in the list **DO**
  - **IF** Maximum density < average density **THEN**
    - Assign maximal density to the segment
    - Recompute average density of remaining segments
  - **ELSE**
    - Assign average density to all remaining segments
    - Break
  - **END**
- **END**
- Complexity : $O(n_i \times \log n_i)$ for each task
- Allow to dynamically add tasks online

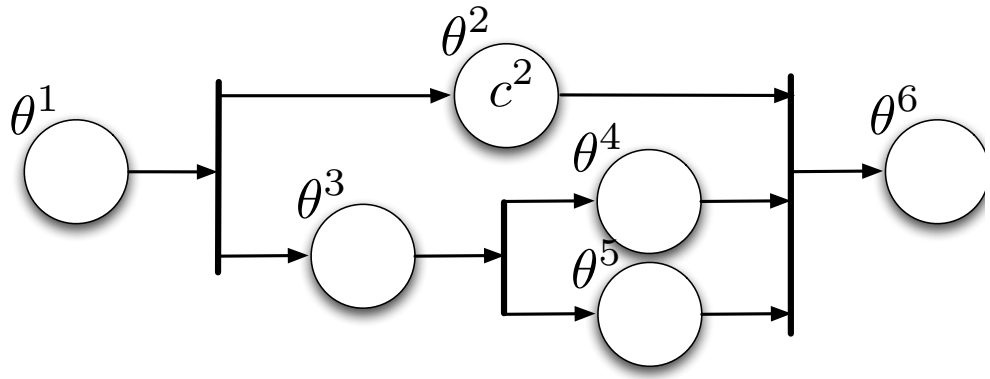
What about performances?



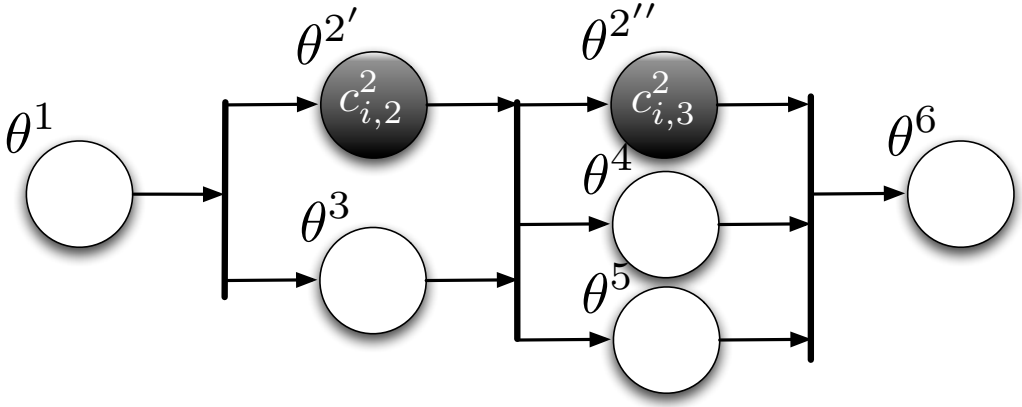
Extension to a More General Model of Multi-Threaded Tasks

- Threads shared by several segments

➔ We reduce it to the previous problem



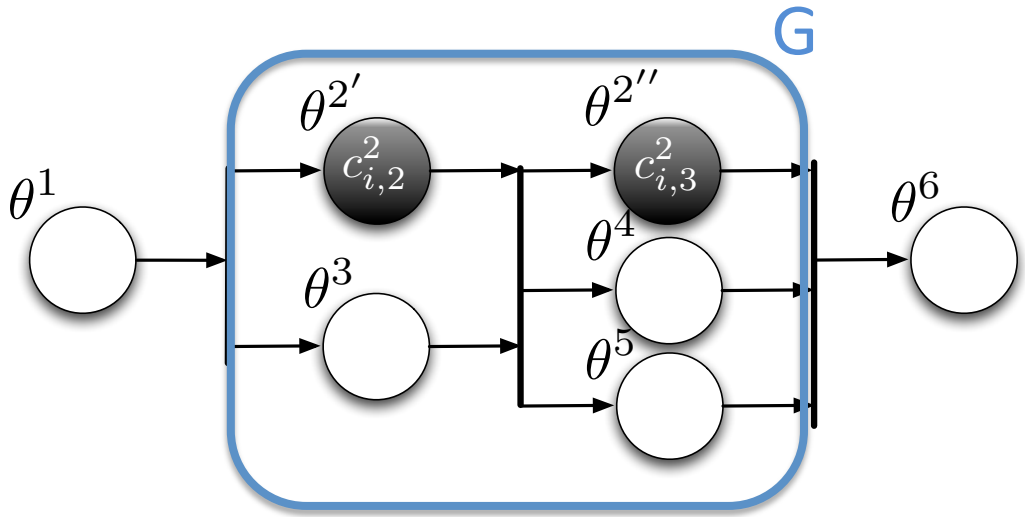
- The **Optimization** problem becomes **non-linear**



Extension to a More General Model of Multi-Threaded Tasks

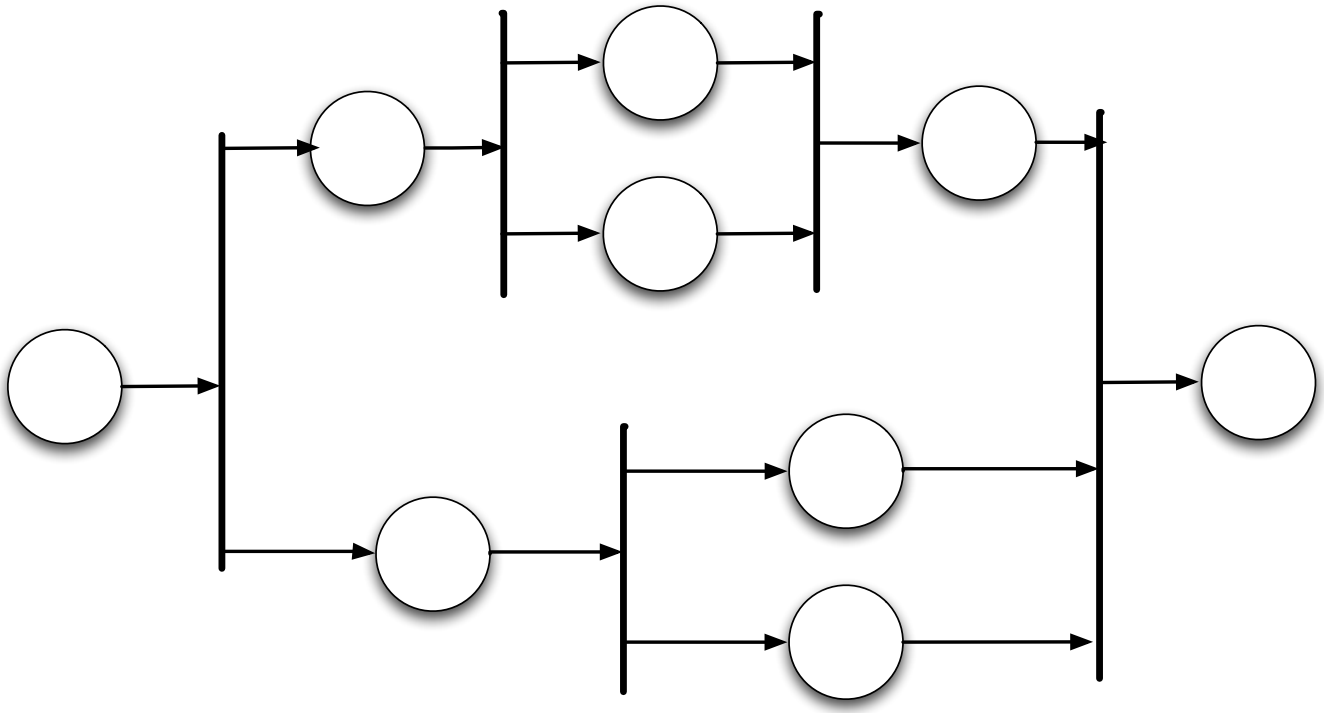
- New difficulties:
  - More variables
    - segment deadline
    - repartition of WCET between segments
  - Decision taken in one segment strongly impacts other segments in G

➔ We need a tool taking into account the properties of many segments



Extension to a More General Model of Multi-Threaded Tasks

- Many parallel branches



Conclusions

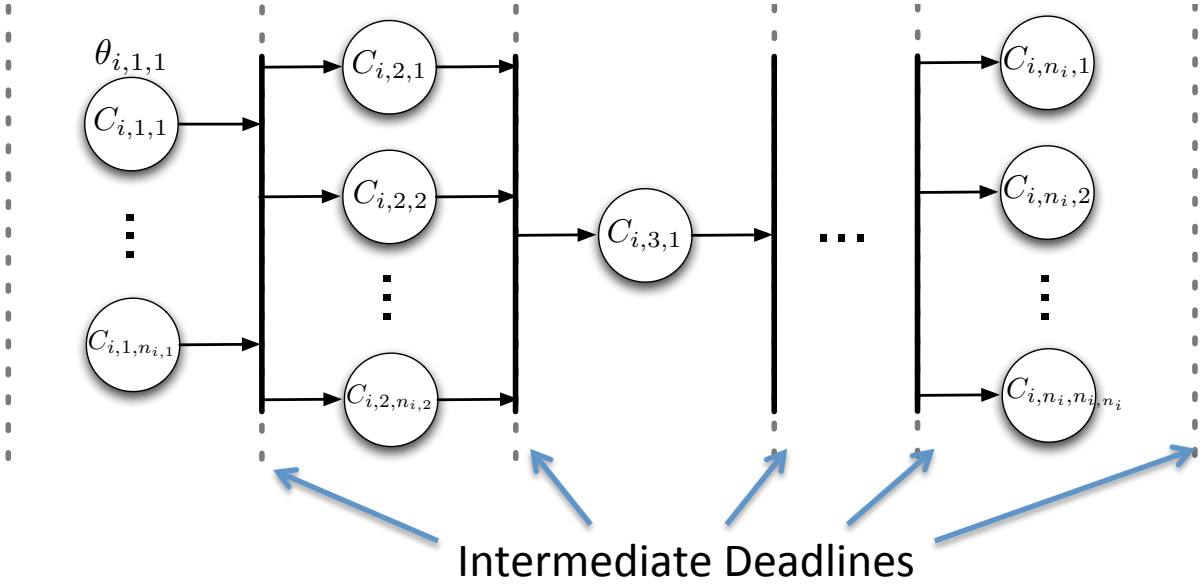
- Provide a way to « convert » a parallel task in a set of sequential task, by adding intermediate deadlines
- Optimal assignment (given we use intermediate deadlines)
- Low computational complexity ($O(n_i \times \log n_i)$ for each task)
- In average, we need 20% less processors than previous work
- Augmentation bound: 2
- Extension to multi-branch tasks

Questions?

Manage the evolution of the task density by fixing the intermediate deadlines

- Number of threads varies ➔ Task density changes with time
- By imposing intermediate deadlines

➔ We can compute the density of each segment independently



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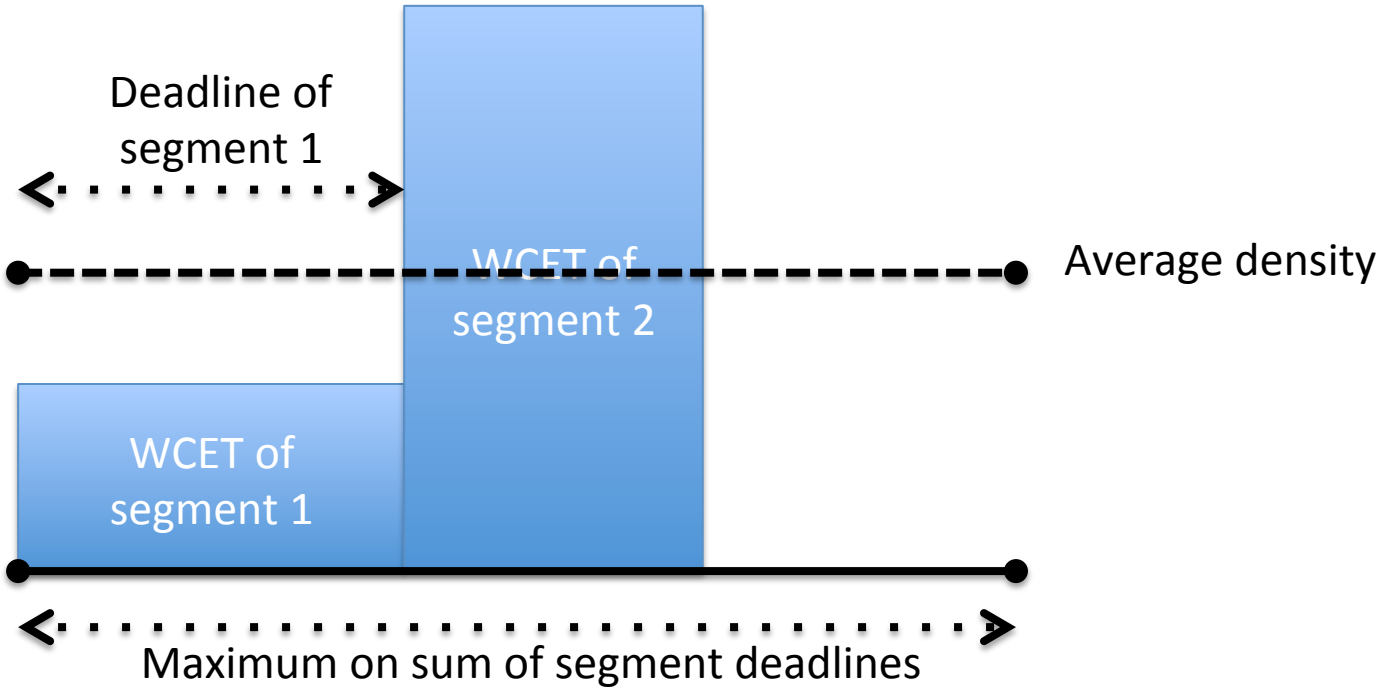

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