Facultat d'Informàtica de Barcelona
Universitat Politècnica de Catalunya

Real-Time Systems

3c-Deadline Monotonic

Antonio Camacho Santiago
antonio.camacho.santiago@upc.edu

Objective

To understand deadline monotonic (DM) schedulers…

To design deadline monotonic schedulers…

To analyze deadline monotonic …

To evaluate the pros and cons of deadline monotonic schedulers…

To compare rate monotonic and deadline monotonic schedulesrs…

```
at design stage:
  assign higher priorities to shorter deadlines tasks

at runtime each Sys_Tick:
  for each active task
    dispatch the task with higher priority
```

Deadline Monotonic scheduler

Deadline monotonic (DM) is a variation of RM suited for tasks where deadlines are less or equal than periods.

Task τ_i	Computing time c_i (ms)	Deadline D_i (ms)	Period T_i (ms)	Priority RM	Priority DM
τ_1	4	10	10	3	2
τ_2	3	15	15	2	1
τ_3	3	8	20	1	3

During the design of the system, each task has a priority according to its deadline

$$\forall \tau_i, \tau_j : D_i < D_j \Rightarrow P_i > P_j$$

It can also be used the following rule saying that priorities are assigned proportionally to the inverse of the period

$$P_i \propto \frac{1}{D_i}$$

At each system tick, the scheduler looks for the existing active tasks to dispatch the task with higher priority. Thus, preemption is allowed at each system tick

Requisites

The first approach for the rate monotonic scheduler is based on periodic tasks as follows:

- 1 microprocessor
- Static tasks
- Periodic tasks
- No precedence among tasks
- The WCET for each tasks is known, fitted and less than its deadline
- Deadlines of each task **are less or** equal to their periods
- **Tasks can be preempted**
- **RT kernel uses fixed priorities**

The schedulability analysis tries to know in advance if all the release times for each task occurs before its deadline.

The analysis is performed at the critical time (not during the whole hiperperiod): for a system of periodic independent tasks scheduled with fixed priorities, each instant in which a task is activated at the same time that each one of the higher priority tasks is called a critical time

Methodology

3c-Deadlime Monotonic

Assign priorities based on deadlines

Task τ_i	Computing time c_i (ms)	Deadline D_i (ms)	Period T_i (ms)	Priority RM	Priority DM
τ_1	4	10	10	3	2
τ_2	3	15	15	2	1
τ_3	3	8	20	1	3

Sufficient condition is not valid

$$U_{\text{total}} = \sum_{i=1}^{n} U_i = \sum_{i=1}^{n} \frac{c_i}{T_i} = \frac{c_1}{T_1} + \frac{c_2}{T_2} + \cdots + \frac{c_n}{T_n} \leq n\left(2^{1/n} - 1\right)$$

Necessary and sufficient condition: check response time analysis for the critical instant

This condition applies to $D_i \leq T_i$

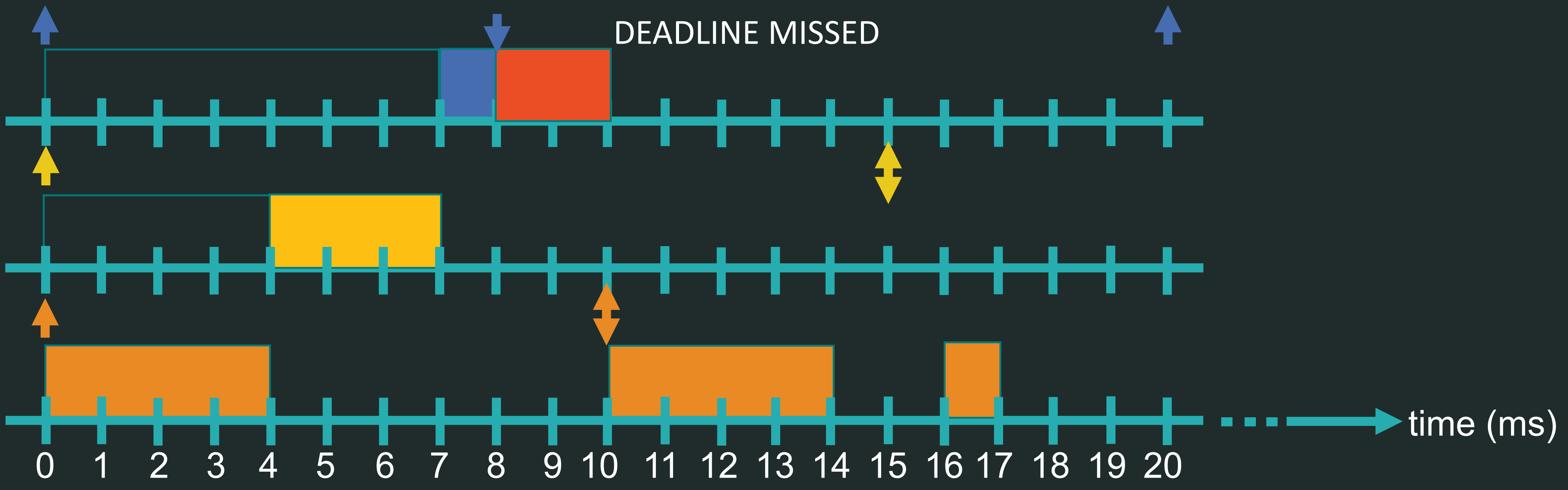
$$\forall \tau_i : R_i = C_i + \sum_{j \in hp(i)} \left\lceil \frac{R_i}{T_j} \right\rceil C_j \leq D_i$$

$$hp(i) = \{ j : 1..n \mid P_j > P_i \}$$

Example RM vs DM

RATE MONOTONIC SCHEDULER

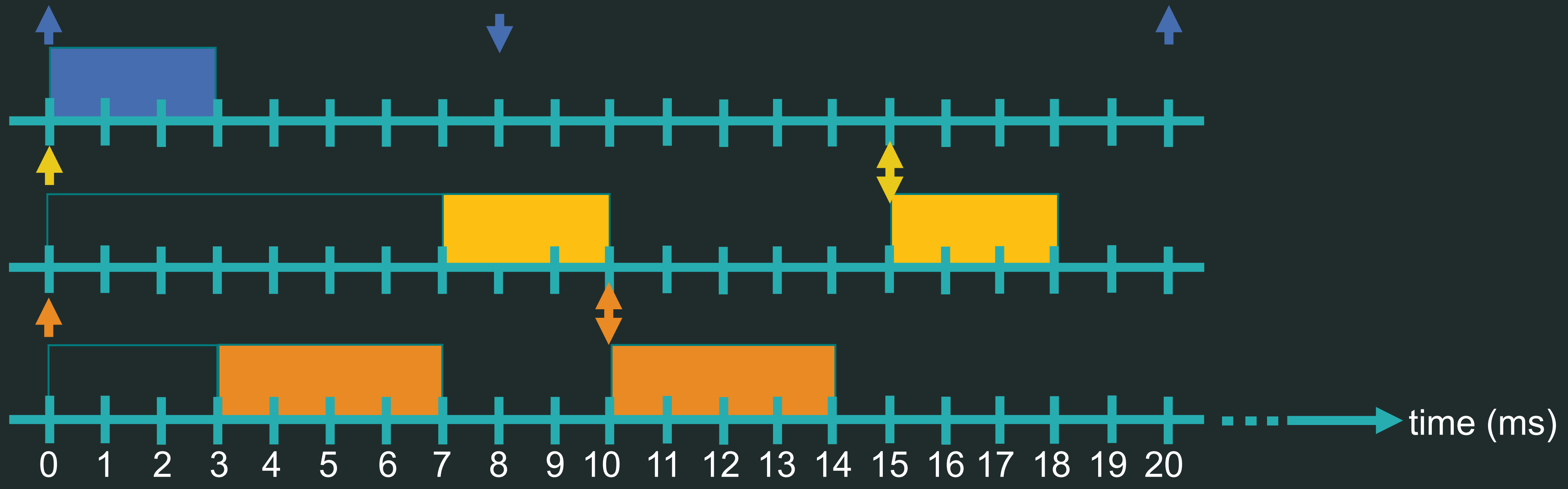
Task τ_i	Computing time c_i (ms)	Deadline D_i (ms)	Period T_i (ms)	Priority RM	Priority DM
τ_1	4	10	10	3	2
τ_2	3	15	15	2	1
τ_3	3	8	20	1	3



Example RM vs DM

DEADLINE MONOTONIC SCHEDULER

Task τ_i	Computing time c_i (ms)	Deadline D_i (ms)	Period T_i (ms)	Priority RM	Priority DM
τ_1	4	10	10	3	2
τ_2	3	15	15	2	1
τ_3	3	8	20	1	3



Example RM vs DM

Response Time Analysis for RM

$$W_i^{n+1} = C_i + \sum_{j \in hp(i)} \left\lceil \frac{W_i^n}{T_j} \right\rceil C_j$$

$i = 1$: $W_1^0 = C_1 + 0 = 4 \leq 10 = D_i$

$i = 2$: $W_2^0 = C_2 + 0 = 3 \leq 15 = D_i$

$$W_2^1 = C_2 + \left\lceil \frac{3}{10} \right\rceil 4 = 3 + 4 = 7 \leq 15 = D_i$$

$$W_2^2 = C_2 + \left\lceil \frac{7}{10} \right\rceil 4 = 3 + 4 = 7 \leq 15 = D_i$$

$$W_2^2 = W_2^1 \rightarrow R_2 = 7$$

$i = 3$: $W_3^0 = C_3 + 0 + 0 = 3 \leq 8 = D_i$

$$W_3^1 = C_3 + \left\lceil \frac{3}{10} \right\rceil 4 + \left\lceil \frac{3}{15} \right\rceil 3 = 3 + 4 + 3 = 10 \geq 8 = D_i \text{ (Deadline missed)}$$

Task τ_i	Computing time c_i (ms)	Deadline D_i (ms)	Period T_i (ms)	Priority RM	Priority DM
τ_1	4	10	10	3	2
τ_2	3	15	15	2	1
τ_3	3	8	20	1	3

Example RM vs DM

Response Time Analysis for DM

Task τ_i	Computing time c_i (ms)	Deadline D_i (ms)	Period T_i (ms)	Priority RM	Priority DM
τ_1	4	10	10	3	2
τ_2	3	15	15	2	1
τ_3	3	8	20	1	3

$$W_i^{n+1} = C_i + \sum_{j \in hp(i)} \left\lceil \frac{W_i^n}{T_j} \right\rceil C_j$$

$i = 3$: $W_3^0 = C_3 + 0 = 3 \leq 8 = D_i$

$i = 1$: $W_1^0 = C_1 + 0 = 4 \leq 10 = D_i$

$$W_1^1 = C_1 + \left\lceil \frac{4}{20} \right\rceil 3 = 4 + 3 = 7 \leq 10 = D_i$$

$$W_1^2 = C_1 + \left\lceil \frac{7}{20} \right\rceil 3 = 4 + 3 = 7 \leq 10 = D_i$$

$$W_1^2 = W_1^1 \rightarrow R_1 = 7$$

$i = 2$: $W_2^0 = C_2 + 0 + 0 = 3 \leq 15 = D_i$

$$W_2^1 = C_2 + \left\lceil \frac{3}{20} \right\rceil 3 + \left\lceil \frac{3}{10} \right\rceil 4 = 3 + 3 + 4 = 10 \leq 15 = D_i$$

$$W_2^2 = C_2 + \left\lceil \frac{10}{20} \right\rceil 3 + \left\lceil \frac{10}{10} \right\rceil 4 = 3 + 4 + 3 = 10 \leq 15 = D_i$$

$$W_2^2 = W_2^1 \rightarrow R_2 = 10$$

Rate Monotonic scheduler

3c-Deadlime Monotonic

Pros:

The deadline monotonic scheduler is based on fixed priorities configured at design stage according to the deadline of each task

Response time analysis is the necessary and sufficient condition

$$\forall \tau_i : R_i = C_i + \sum_{j \in hp(i)} \left\lceil \frac{R_i}{T_j} \right\rceil C_j \le D_i$$

Optimality: among all the fixed priorities policies with deadlines less or equal to periods, DM is optimal, i.e. if some priority assignment ensures schedulability, then DM will also ensure it (converse is not truth).

On the limit, when periods are equal to deadlines, RM coincides with DM

Cons:

Preemption

Performance depends on the system tick

Sufficient condition $U_{\text{total}} \le n\left(2^{1/n} - 1\right)$ is not valid