Real-Time Scheduling

CIS700

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Outline

- Real-time systems
- Real-time scheduling algorithms
  - Fixed-priority algorithm (RM)
  - Dynamic-priority algorithm (EDF)

Real-Time Systems

- Definition
  - Systems whose correctness depends on their temporal aspects as well as their functional aspects

- Performance measure
  - Timeliness on timing constraints (deadlines)
  - Speed/average case performance are less significant.

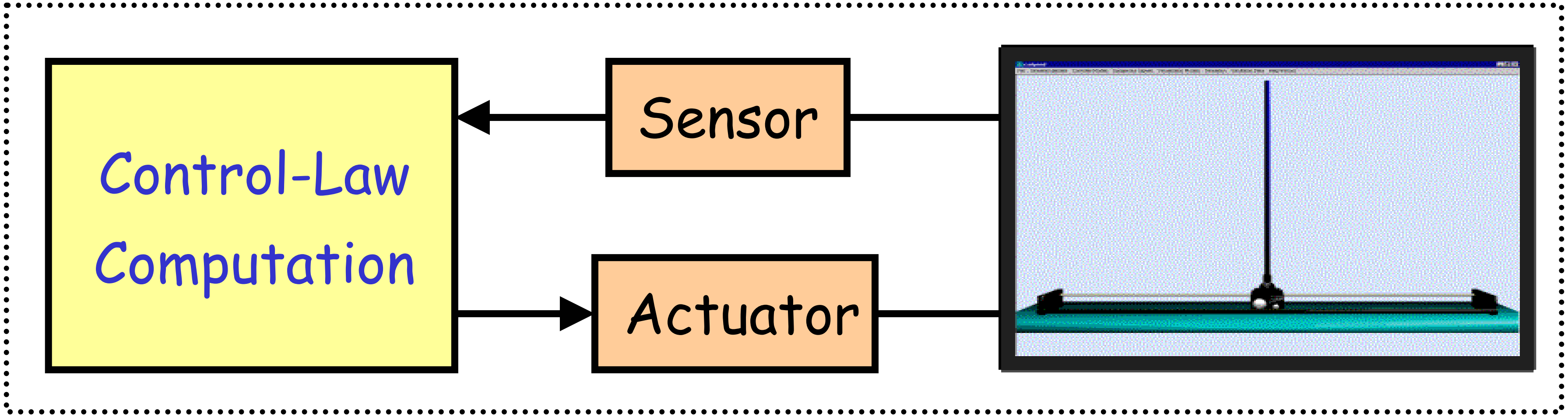
- Key property
  - Predictability on timing constraints

Real-Time System Example

- Digital control systems
  - periodically performs the following job:

senses the system status and

actuates the system according to its current status



Real-Time System Example

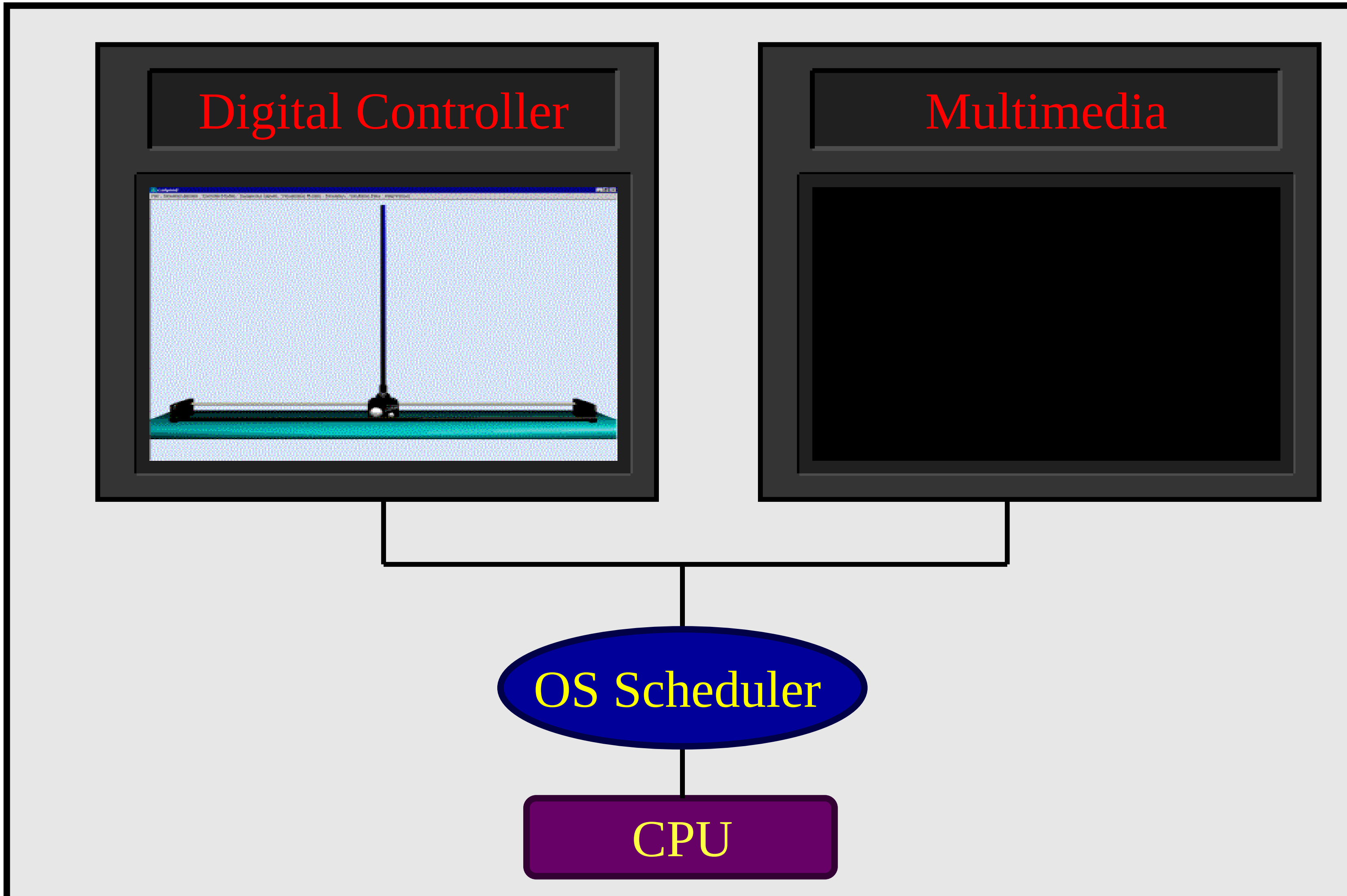
- Multimedia applications
  - periodically performs the following job:

    reads, decompresses, and displays video and audio streams

Fundamental Real-Time Issue

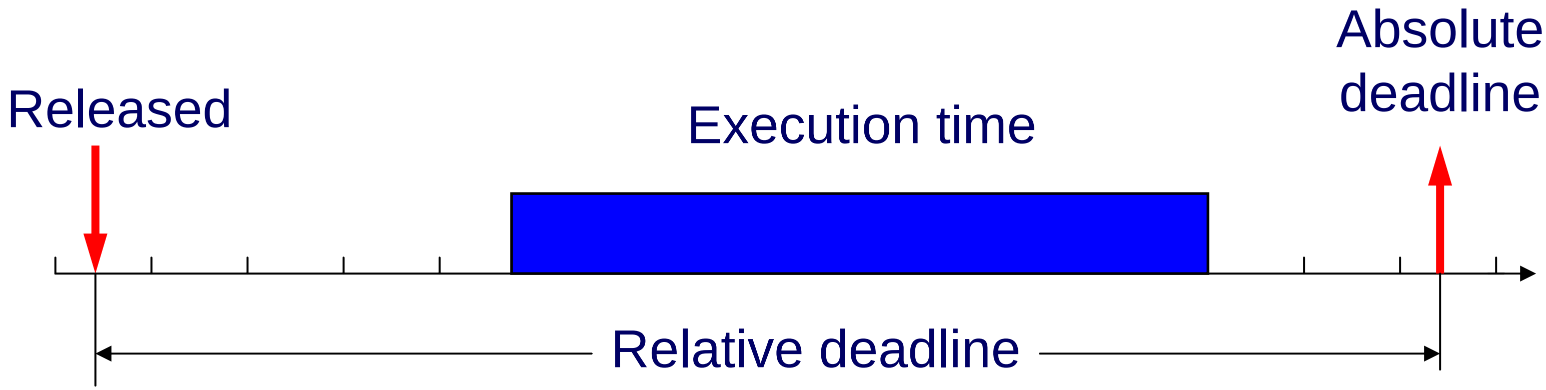
- To specify the timing constraints of real-time systems
- To achieve predictability on satisfying their timing constraints, possibly, with the existence of other real-time systems

Scheduling Framework Example



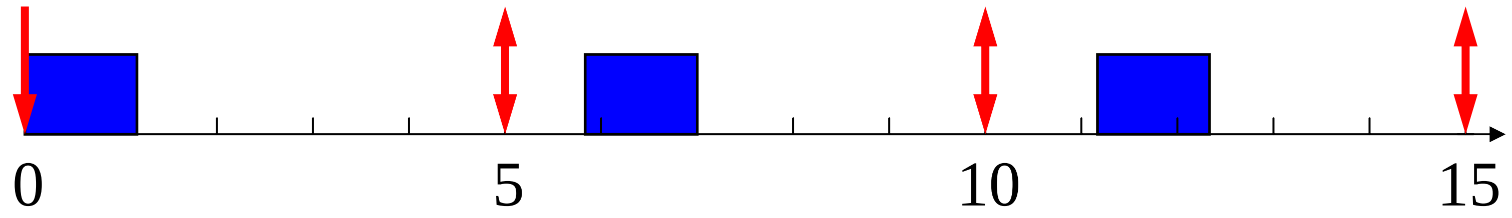
Real-Time Workload

- Job (unit of work)
  - a computation, a file read, a message transmission, etc
- Attributes
  - Resources required to make progress
  - Timing parameters



Real-Time Task

- Task : a sequence of similar jobs
  - Periodic task (*p*,*e*)
    - Its jobs repeat regularly
    - Period *p* = inter-release time (0 < *p*)
    - Execution time *e* = maximum execution time (0 < *e* < *p*)
    - Utilization U = e/p



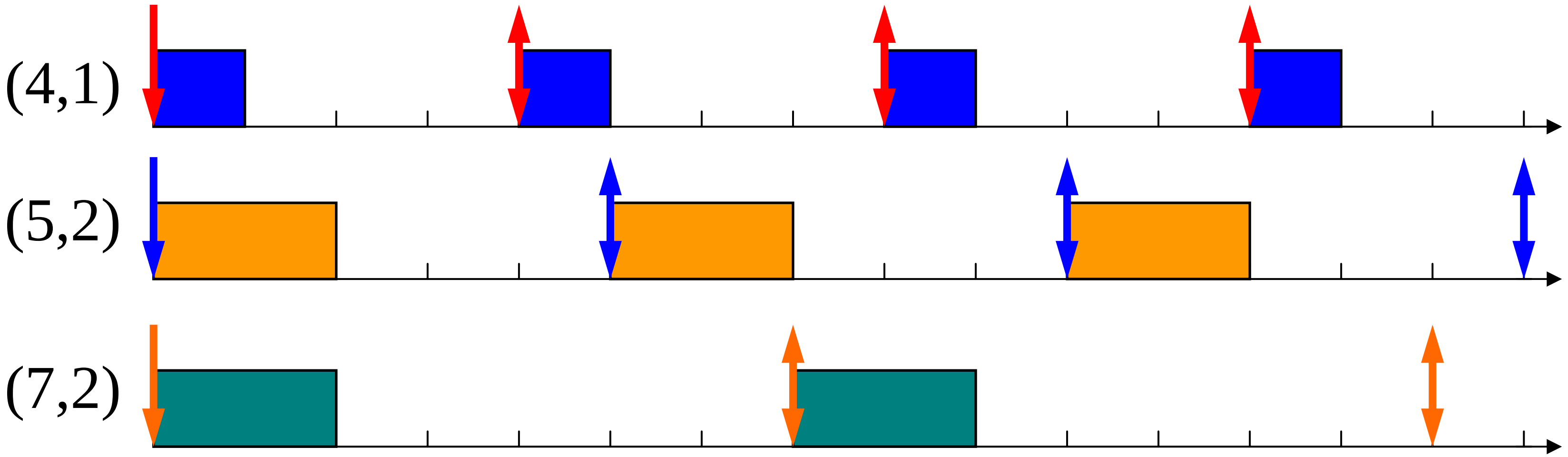
Deadlines: Hard vs. Soft

- Hard deadline
  - Disastrous or very serious consequences may occur if the deadline is missed
  - Validation is essential : can all the deadlines be met, even under worst-case scenario?
  - Deterministic guarantees

- Soft deadline
  - Ideally, the deadline should be met for maximum performance. The performance degrades in case of deadline misses.
  - Best effort approaches / statistical guarantees

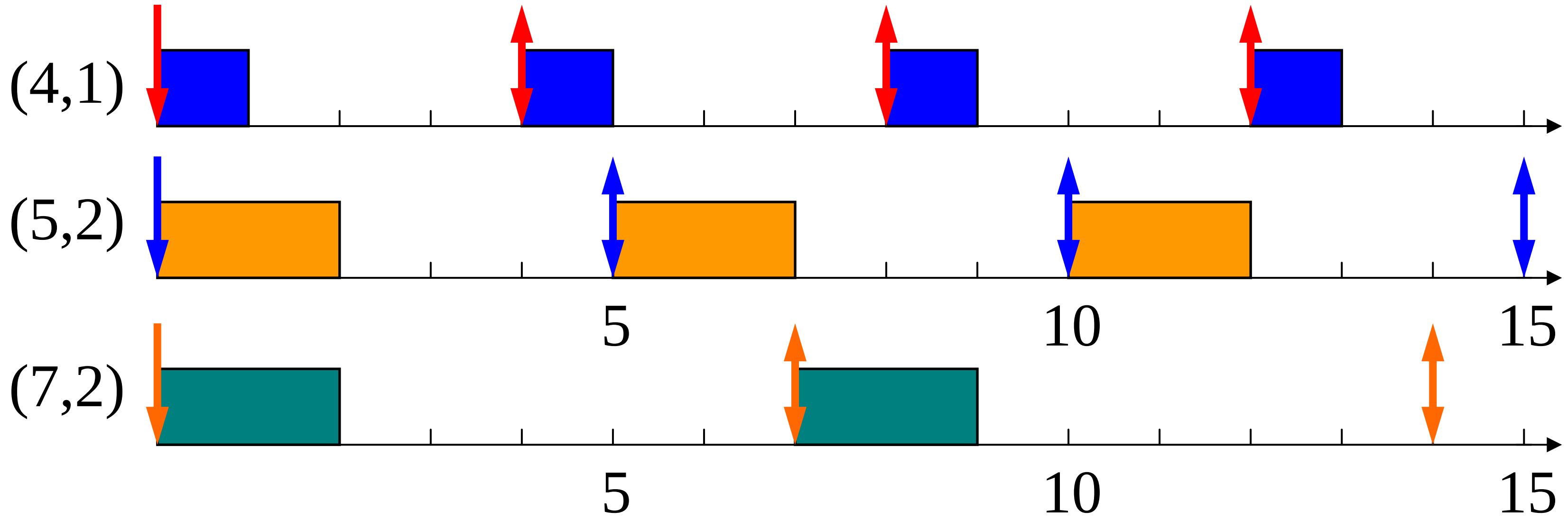
Schedulability

- Property indicating whether a real-time system (a set of real-time tasks) can meet their deadlines



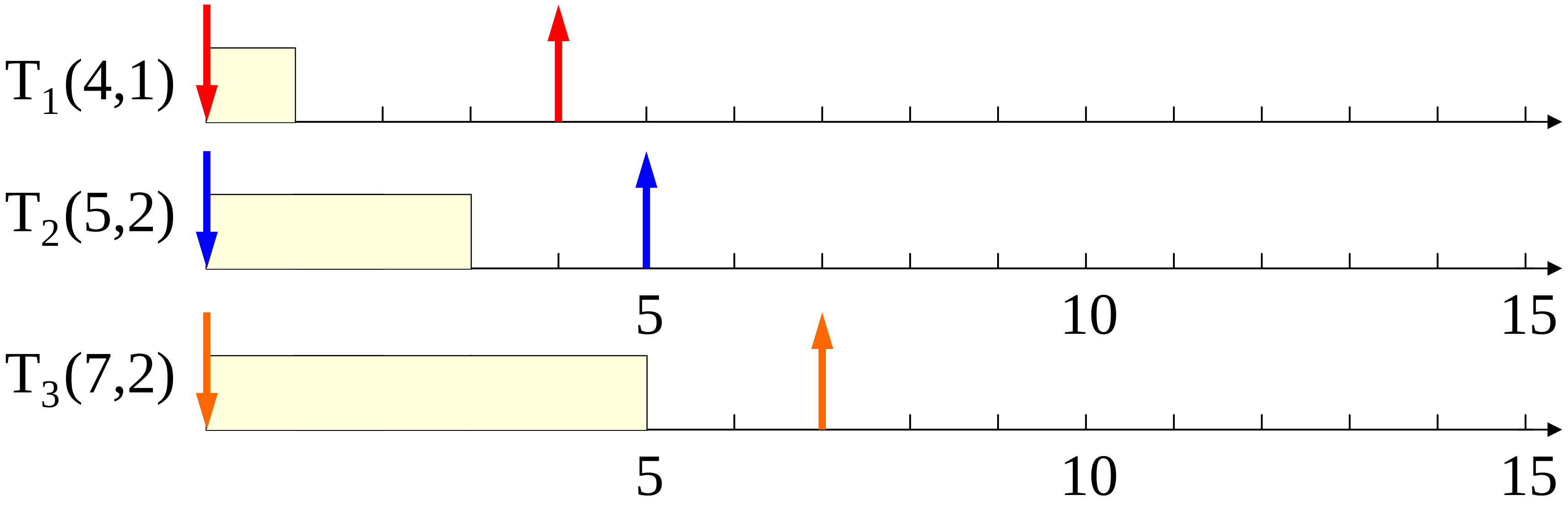
Real-Time Scheduling

- Determines the order of real-time task executions
- Static-priority scheduling
- Dynamic-priority scheduling



RM (Rate Monotonic)

- Optimal static-priority scheduling
- It assigns priority according to period
- A task with a shorter period has a higher priority
- Executes a job with the shortest period



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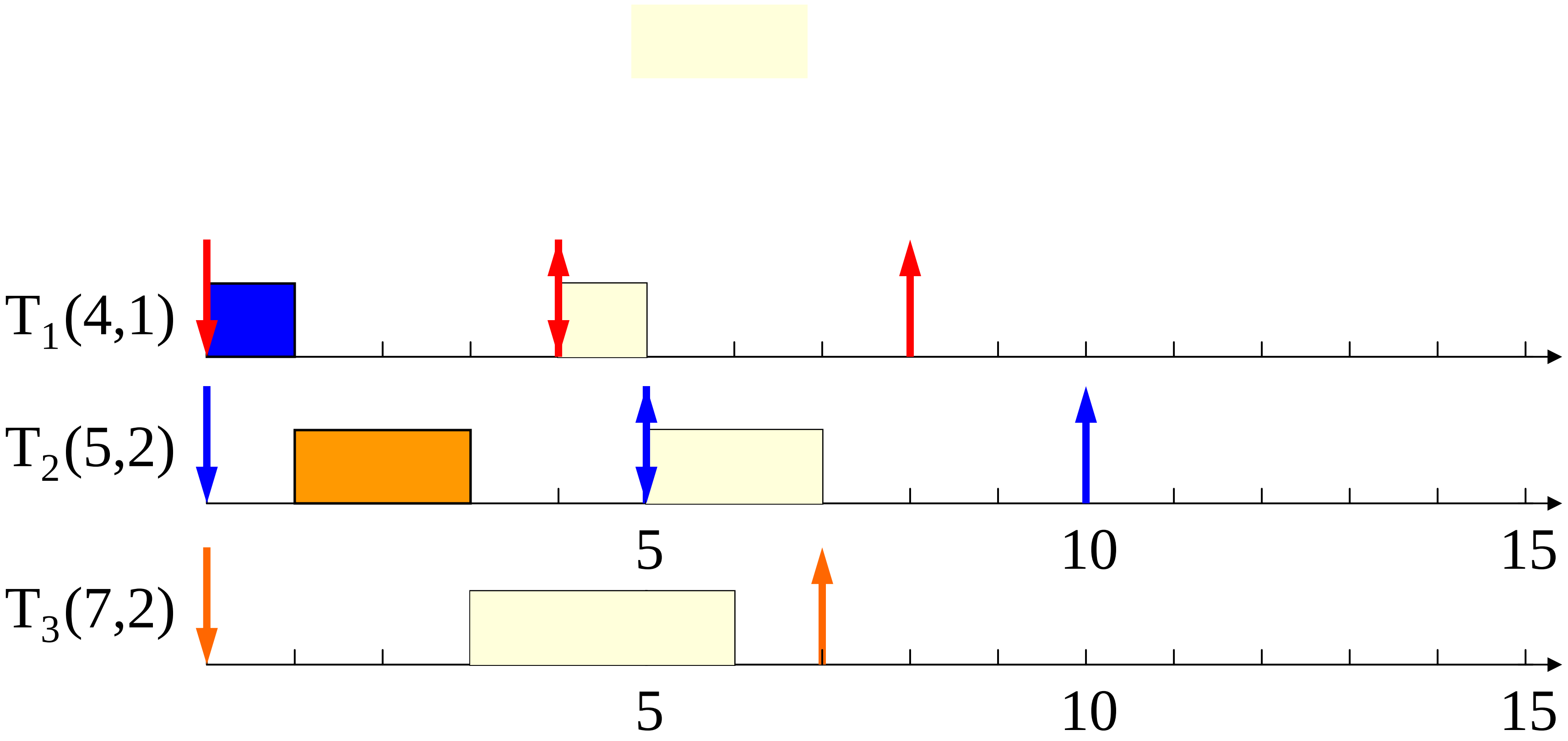

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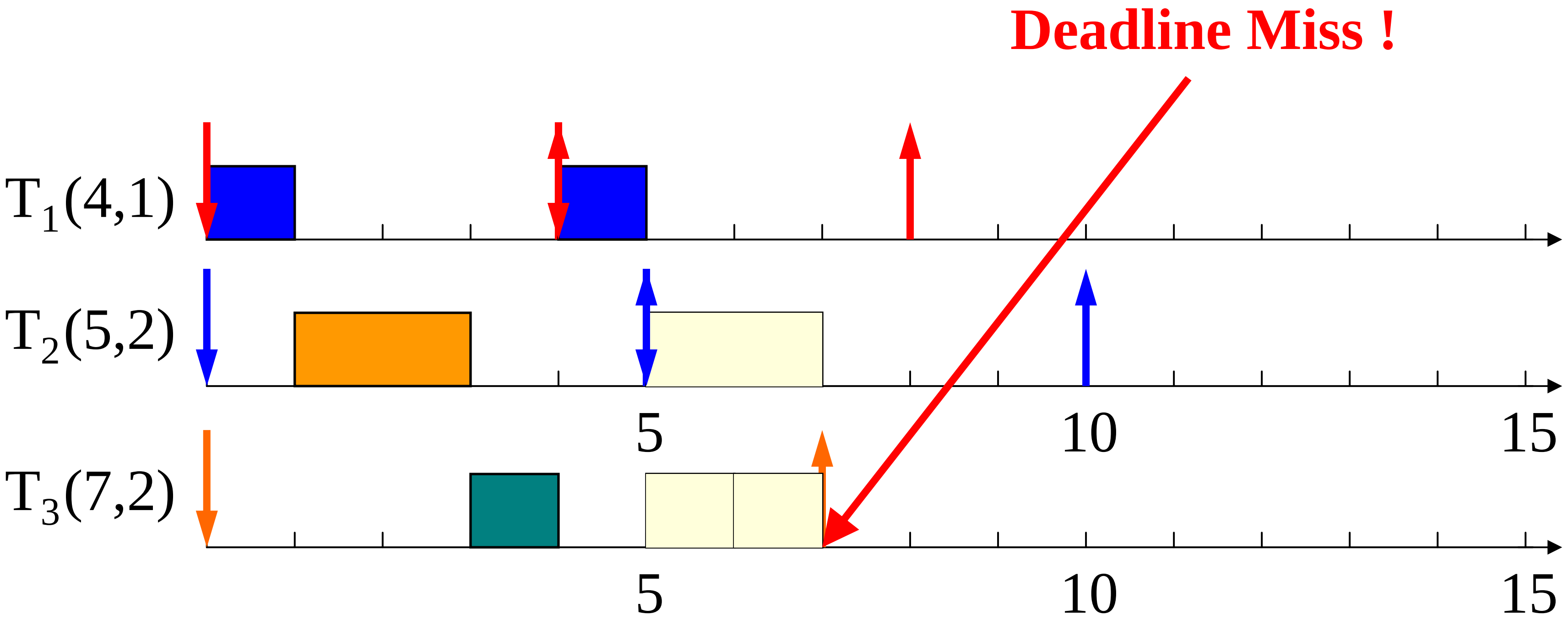
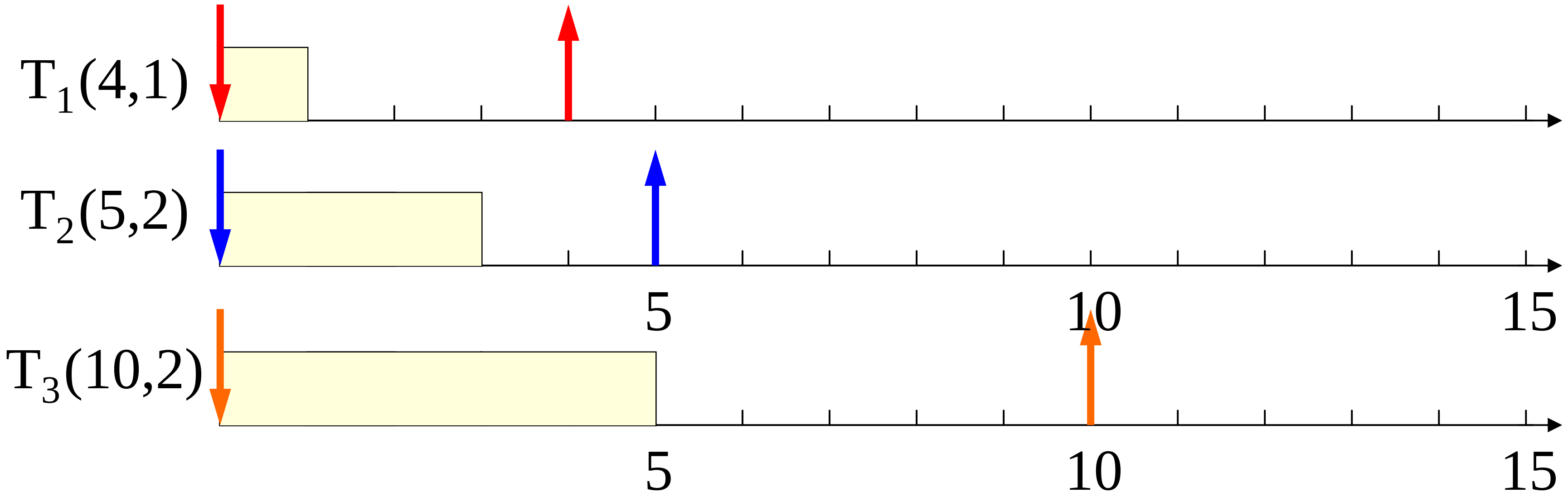


Response Time

- Response time
  - Duration from released time to finish time



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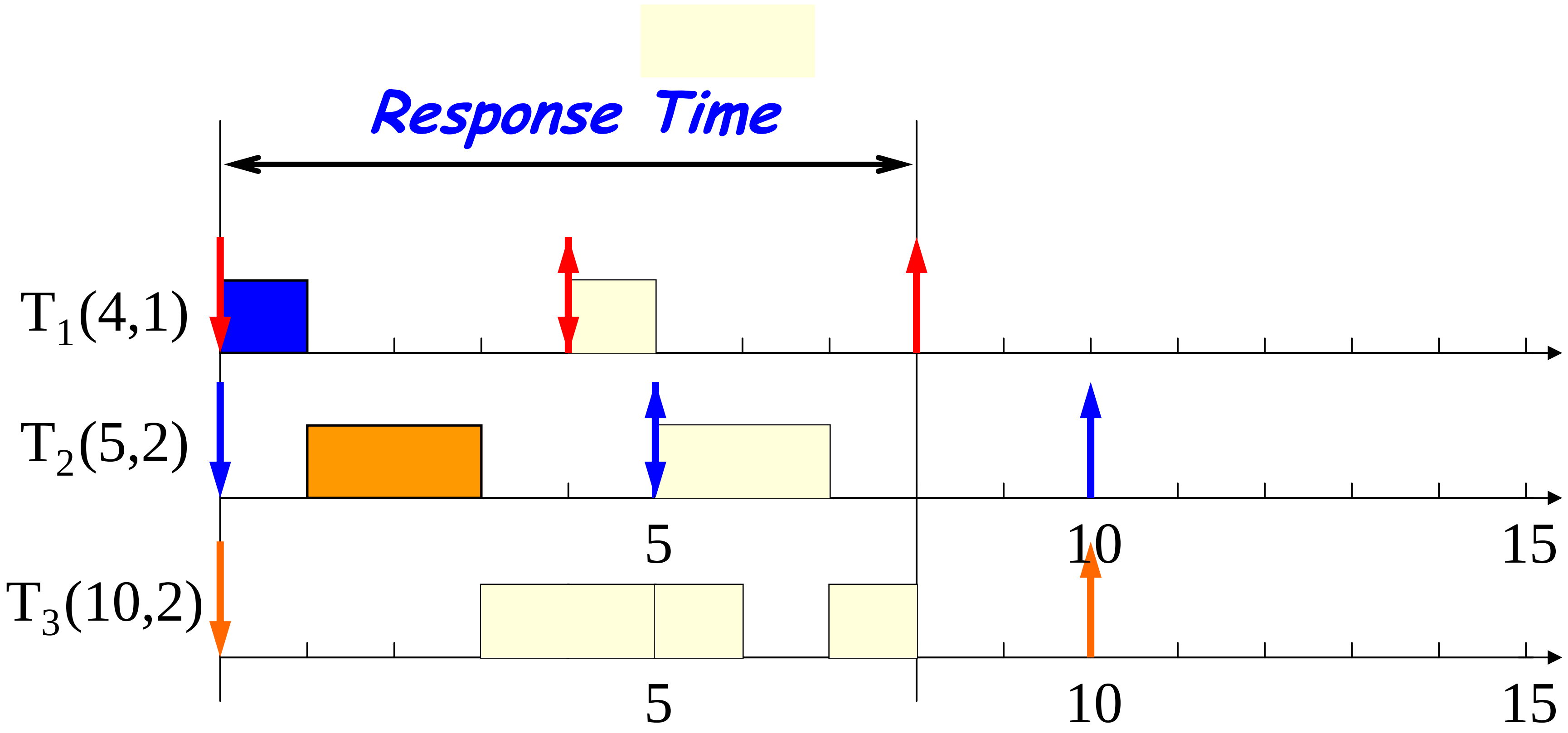
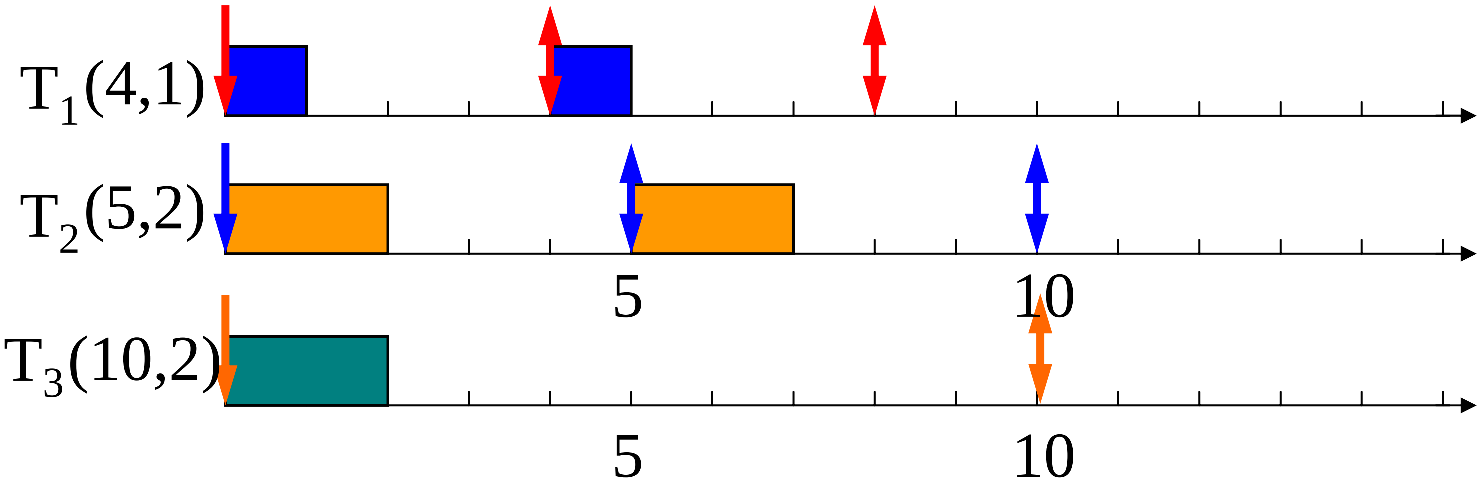


Response Time

- Response Time (r_i) [Audsley et al., 1993]

$$r_i = e_i + \sum_{T_k \in HP(T_i)} \left\lceil \frac{r_i}{p_k} \right\rceil \cdot e_k$$

- HP(T_i) : a set of higher-priority tasks than T_i



RM - Schedulability Analysis

- Real-time system is schedulable under RM
  if and only if $r_i \leq p_i$ for all task $T_i(p_i,e_i)$

Joseph & Pandya,
"Finding response times in a real-time system",
The Computer Journal, 1986.

RM – Utilization Bound

- Real-time system is schedulable under RM if

$$\sum U_i \leq n\,(2^{1/n}-1)$$

Liu & Layland,
"Scheduling algorithms for multi-programming in a hard-real-time environment", Journal of ACM, 1973.

RM – Utilization Bound

- Real-time system is schedulable under RM if

$$\sum U_i \le n\,(2^{1/n}-1)$$

- Example: $T_1(4,1)$, $T_2(5,1)$, $T_3(10,1)$,

$$\sum U_i = 1/4 + 1/5 + 1/10$$
$$= 0.55$$
$$3\,(2^{1/3}-1) \approx 0.78$$

Thus, $\{T_1, T_2, T_3\}$ is schedulable under RM.

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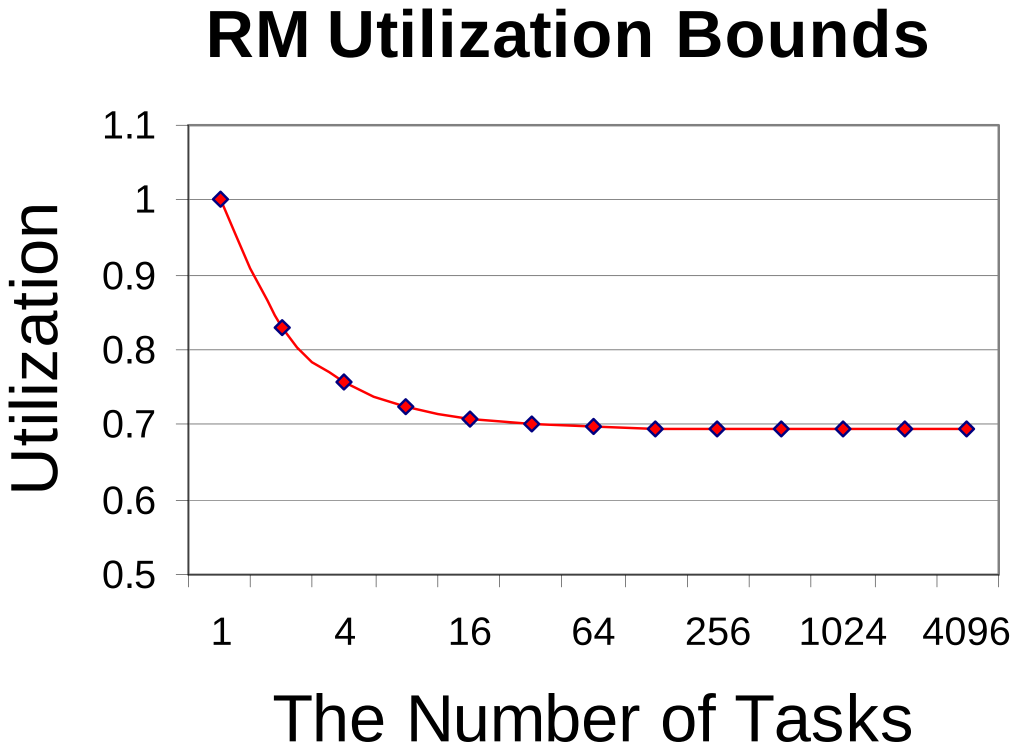
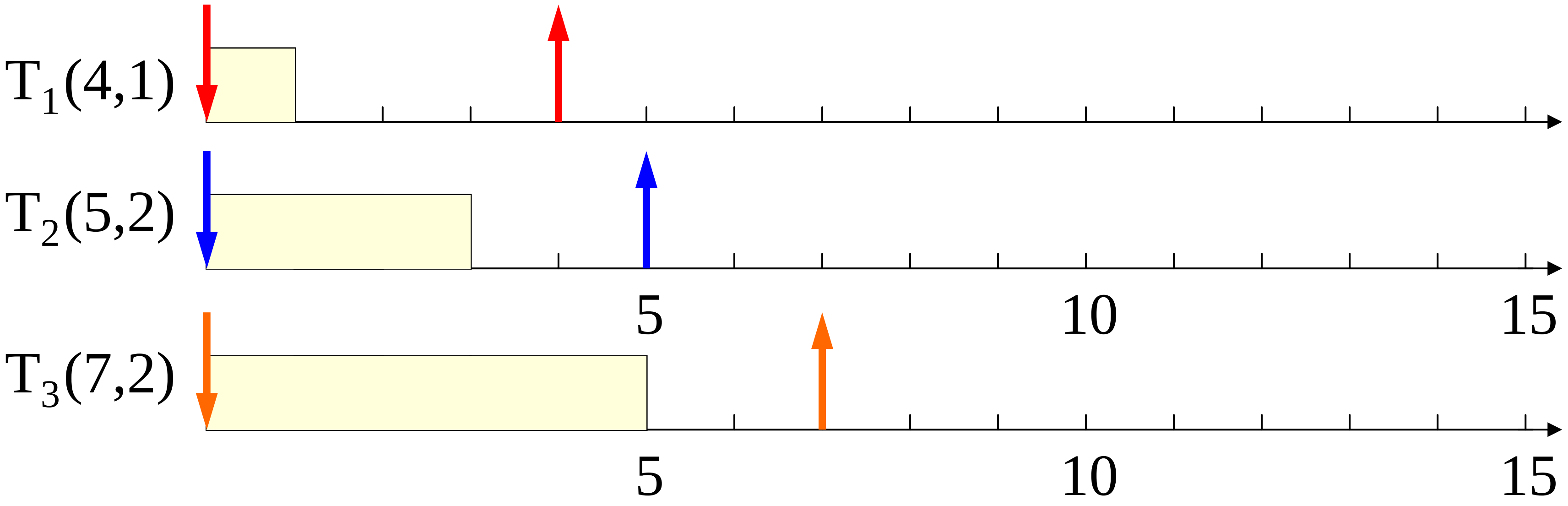


EDF (Earliest Deadline First)

- Optimal dynamic priority scheduling
- A task with a shorter deadline has a higher priority
- Executes a job with the earliest deadline



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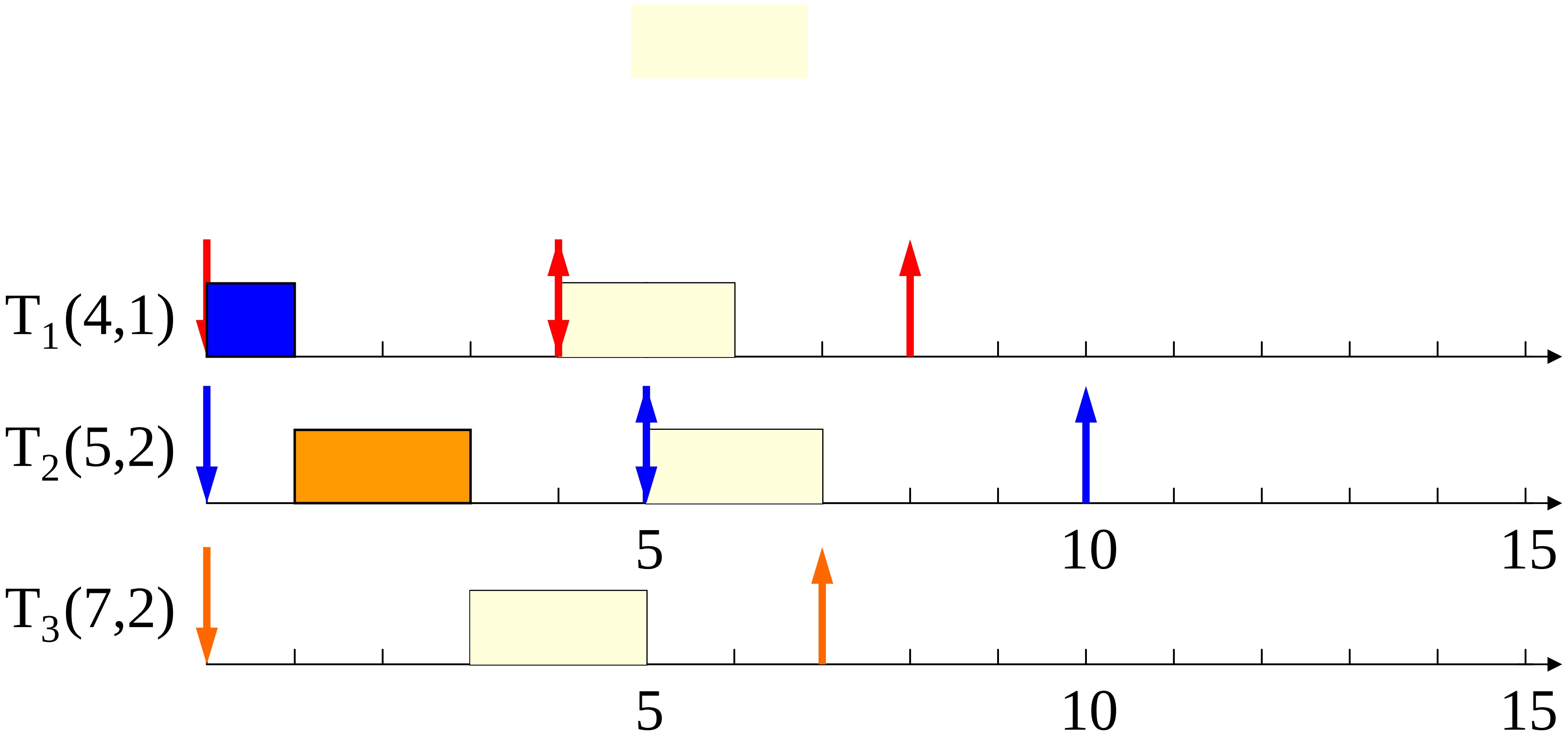

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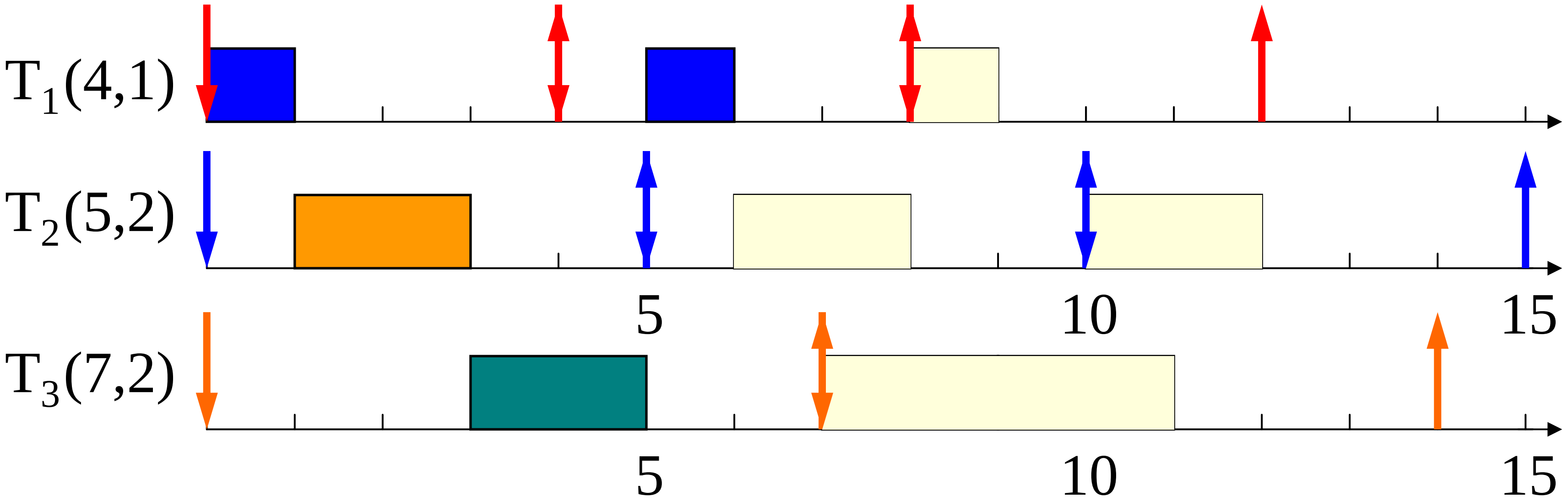

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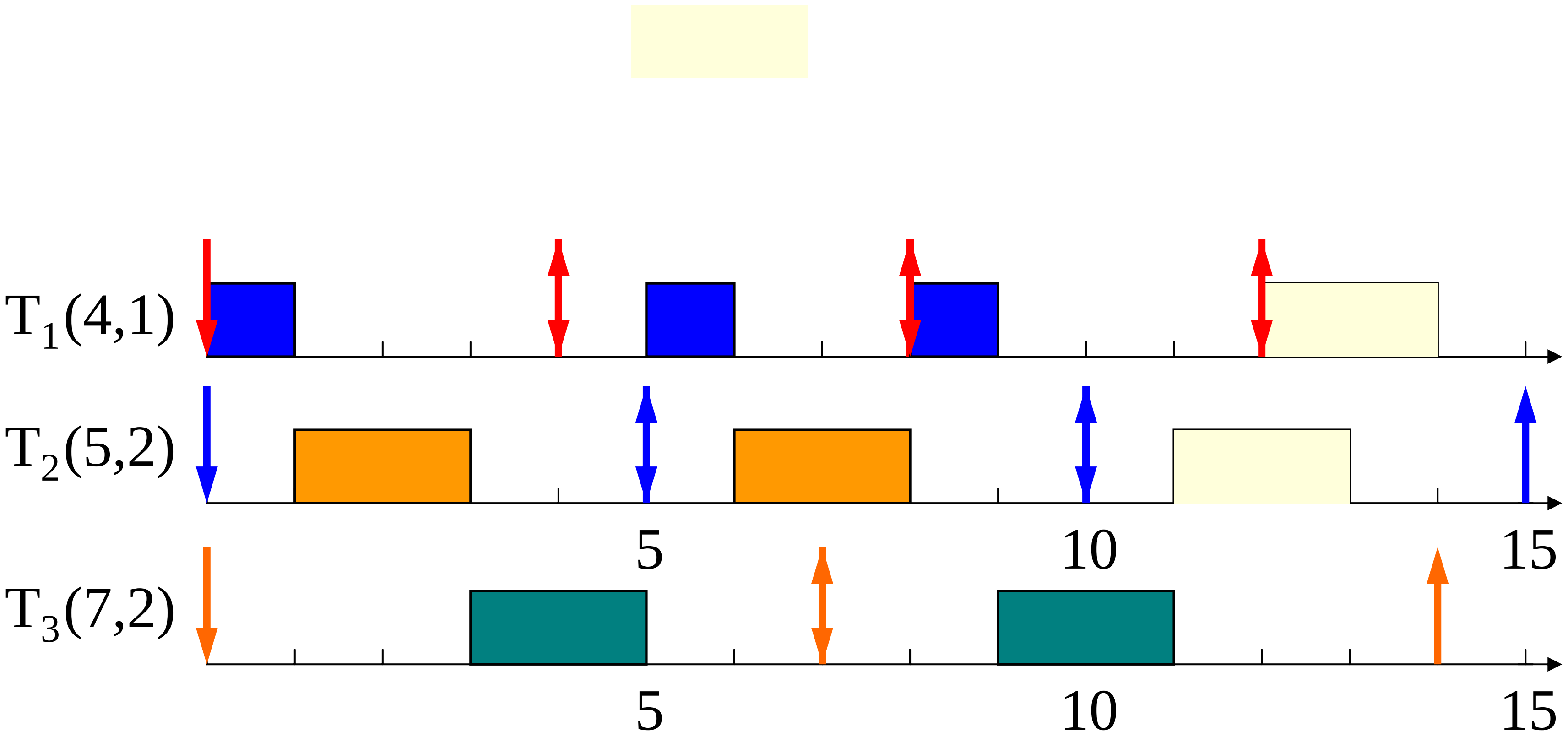
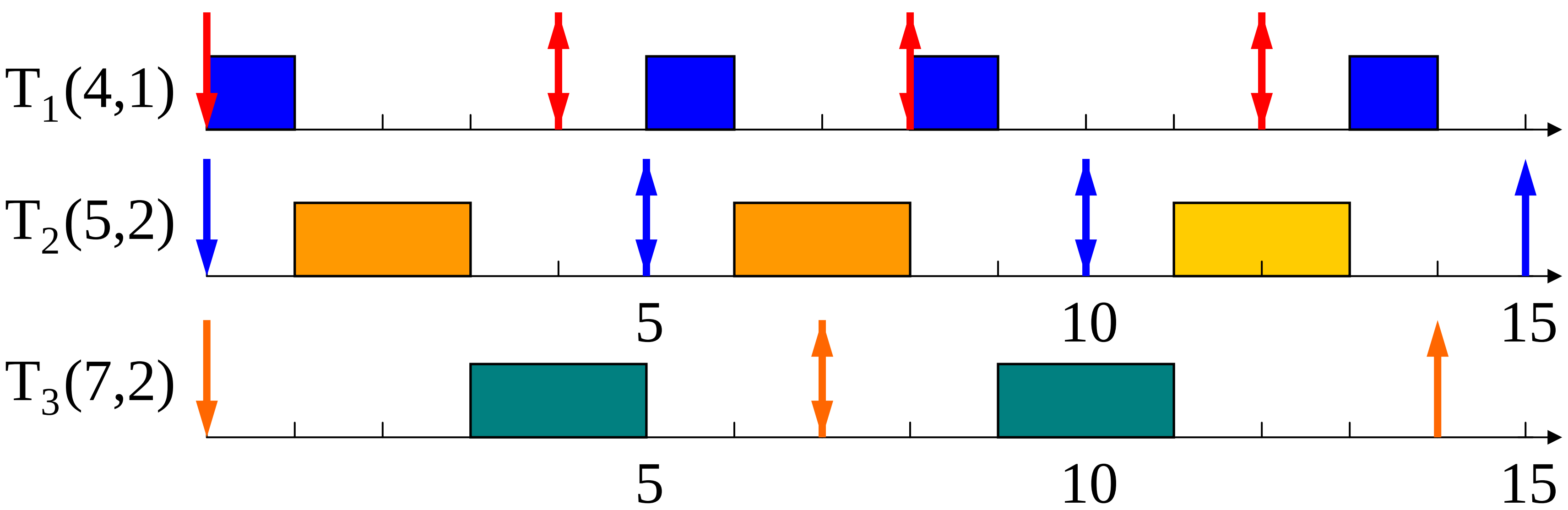


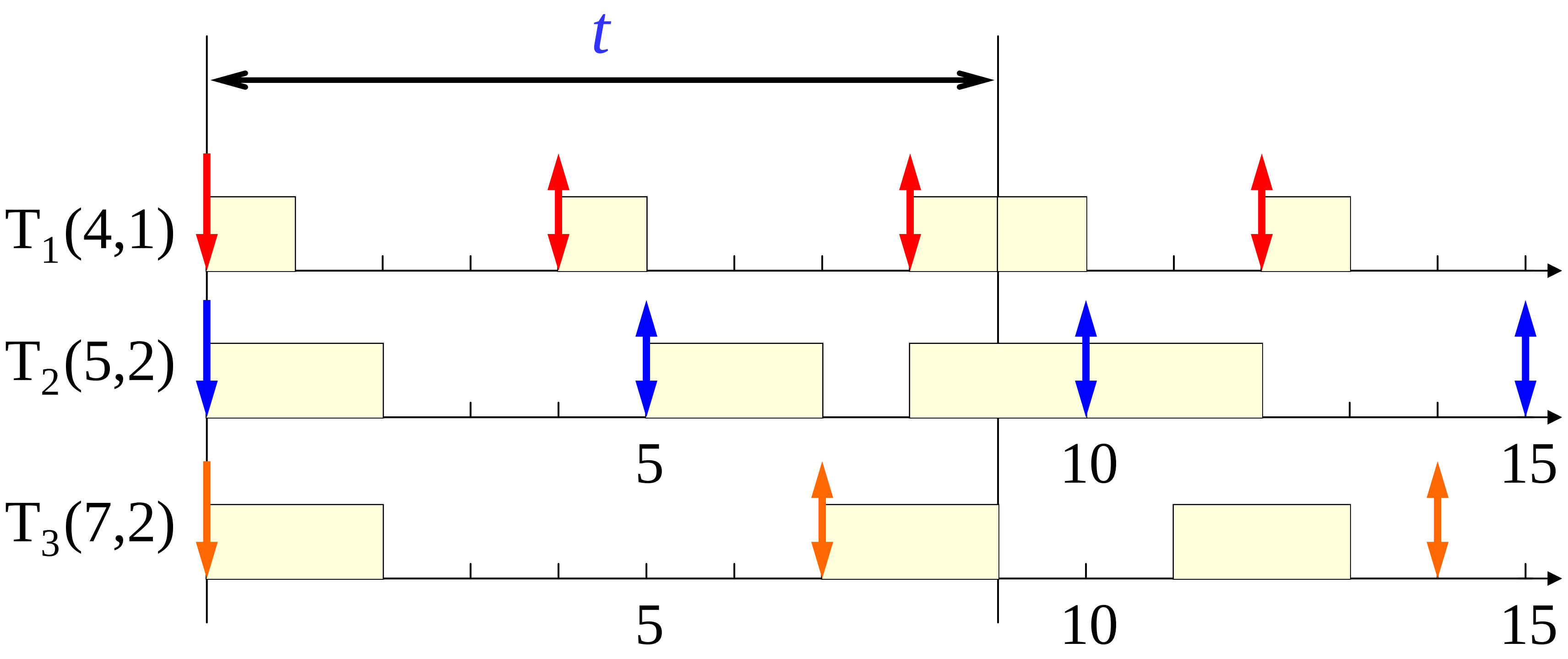
EDF (Earliest Deadline First)

- Optimal scheduling algorithm
  - if there is a schedule for a set of real-time tasks, EDF can schedule it.



Processor Demand Bound

- Demand Bound Function : *dbf(t)*
  - the maximum processor demand by workload over any interval of length t



EDF - Schedulability Analysis

- Real-time system is schedulable under EDF

  if and only if **dbf(t) ≤ t** for all interval t

  Baruah et al.
  "Algorithms and complexity concerning the preemptive scheduling of periodic, real-time tasks on one processor", Journal of Real-Time Systems, 1990.

- Demand Bound Function : dbf(t)
  - the maximum processor demand by workload over any interval of length t

EDF – Utilization Bound

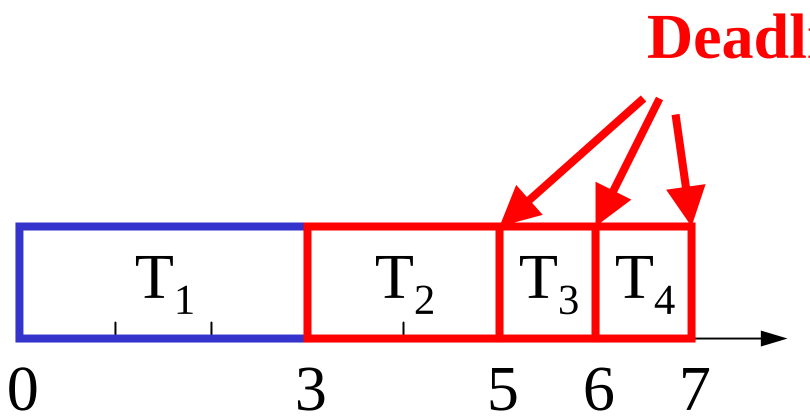
- Real-time system is schedulable under EDF if and only if

$$\sum U_i \leq 1$$

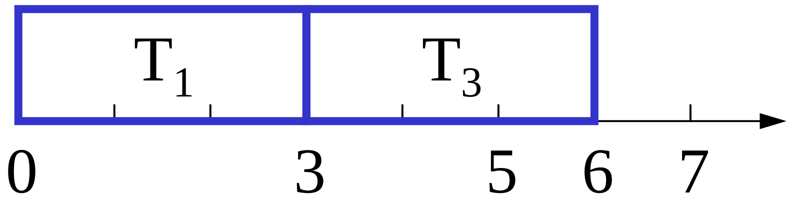
Liu & Layland,
"Scheduling algorithms for multi-programming in a hard-real-time environment", Journal of ACM, 1973.

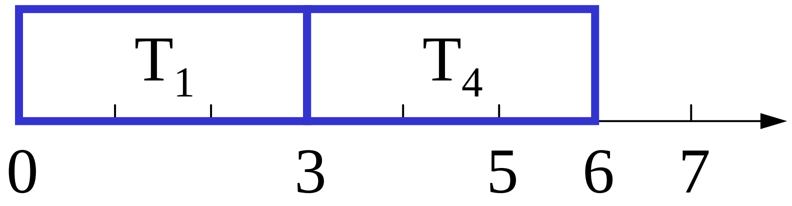
EDF – Overload Conditions

- Domino effect during overload conditions
  - Example: $T_1(4,3)$, $T_2(5,3)$, $T_3(6,3)$, $T_4(7,3)$



Better schedules :





RM vs. EDF

- Rate Monotonic
  - Simpler implementation, even in systems without explicit support for timing constraints (periods, deadlines)
  - Predictability for the highest priority tasks
- EDF
  - Full processor utilization
  - Misbehavior during overload conditions
- For more details: Buttazzo, “Rate monotonic vs. EDF: Judgement Day”, EMSOFT 2003.