Midterm Information

- Midterm will be on Oct. 22. The midterm will last 60 minutes!
  - Location: PGCLL B138 (capacity 620)
  - Time: 6pm to 7pm
- One page double sided cheat sheet is allowed.
- Office Hour for midterm will be on Oct. 22^{nd}, class time.
- If you have a conflict, you can take the midterm 2 to 3 on the same day.
  - Location ITB 222

Real Time Systems and Control Applications

Contents:

Deadline Monotonic Scheduling

Earliest Deadline First Scheduling

Sufficient Condition and Necessary Condition

A➔B   Meaning: If A (hypothesis), then B (conclusion).

- A is sufficient condition for B
- B is necessary condition for A
- If A➔B is valid, we can also infer that !B ➔!A (inverse and negative statement) is valid.

Example:

- A person must have talent to become a world-class sports player.
  - “have talent” is necessary condition for “world-class player”
  - It means if one has talent, he/she may not be a world-class player; but a world-class player must have talent.
- Its inverse and negative statement is

  “A person cannot be a world-class sports player if without talent.”

Questions

(1) What if $p_i \neq D_i$?

A: We replace pi with min(Di; pi) in the above expression.

(2) Determine if the following set of tasks is RM schedulable: (50, 10), (80, 20), (110, 40), (190, 50)

(3) How about just : (50, 10), (80, 20), (110, 40) using RM?

Solution to Question (2)

$$\omega_i(t) = \sum_{k=1}^{i} \left\lceil \frac{t}{p_k} \right\rceil e_k \le t$$

$$0 \le t \le p_i$$

where $t = k_j p_j, \quad (j = 1, \dots . i\,)\; and\; k_j = 1, \dots, \left\lfloor \frac{p_i}{p_j} \right\rfloor$

- (2) Using Test 3: (5,1), (8,2), (11,4), (19,5)
- When i=1, t=1 => w1(t) = 1 < 5 (OK)

- When i=2,
- t1= 1 for task 1, t2=1 for task 2, so t=5, 8=> w2(5) = e1+e2 =3 <5, w2(8)=2e1+e2=4<8 (OK)

- When i=3, possible t1=1,2; t2=1; t3=1, so possible t values are: t=5,10, 8, 11
- w3(5) = e1+e2+e3=7>5
- w3(8)= 2e1+e2+e3=8=t (OK) (You can stop here for i=3 case)
- w3(10) = 2e1+2e2+e3=t (OK)
- w(11) = 3e1+ 2e2+e3=t (OK)

Continued..

- When i=4, t1=1,2,3; t2=1,2; t3=1; t4=1, so possible t values are: 5,10,15,8,16,11,19
- w4(5) = e1+e2+e3+e4=1+2+4+5=12>5
  w4(8) = 2e1+e2+e3+e4=2+2+4+5=13>8
  w4(10) = 2e1+2e2+e3+e4=2+4+4+5=15>10
  w4(11) = 3e1+2e2+1e3+e4=3+4+4+5=16>11
  w4(15) =3e1+2e2+2e3+e4=20>15
  w4(16) =4e1+2e2+2e3+e4=21>16
  w4(19) =4e1+3e2+2e3+e4=23>19

(Not schedulable)

Actually, if you consider utilization, you will get 0,2+0.25+0.3636+0.2636>100% (It is not schedulable)

Solution to Question (3)

(3) Based on the process shown in (2), the first 3 tasks are schedulable under RM, though the utilization is over 80%

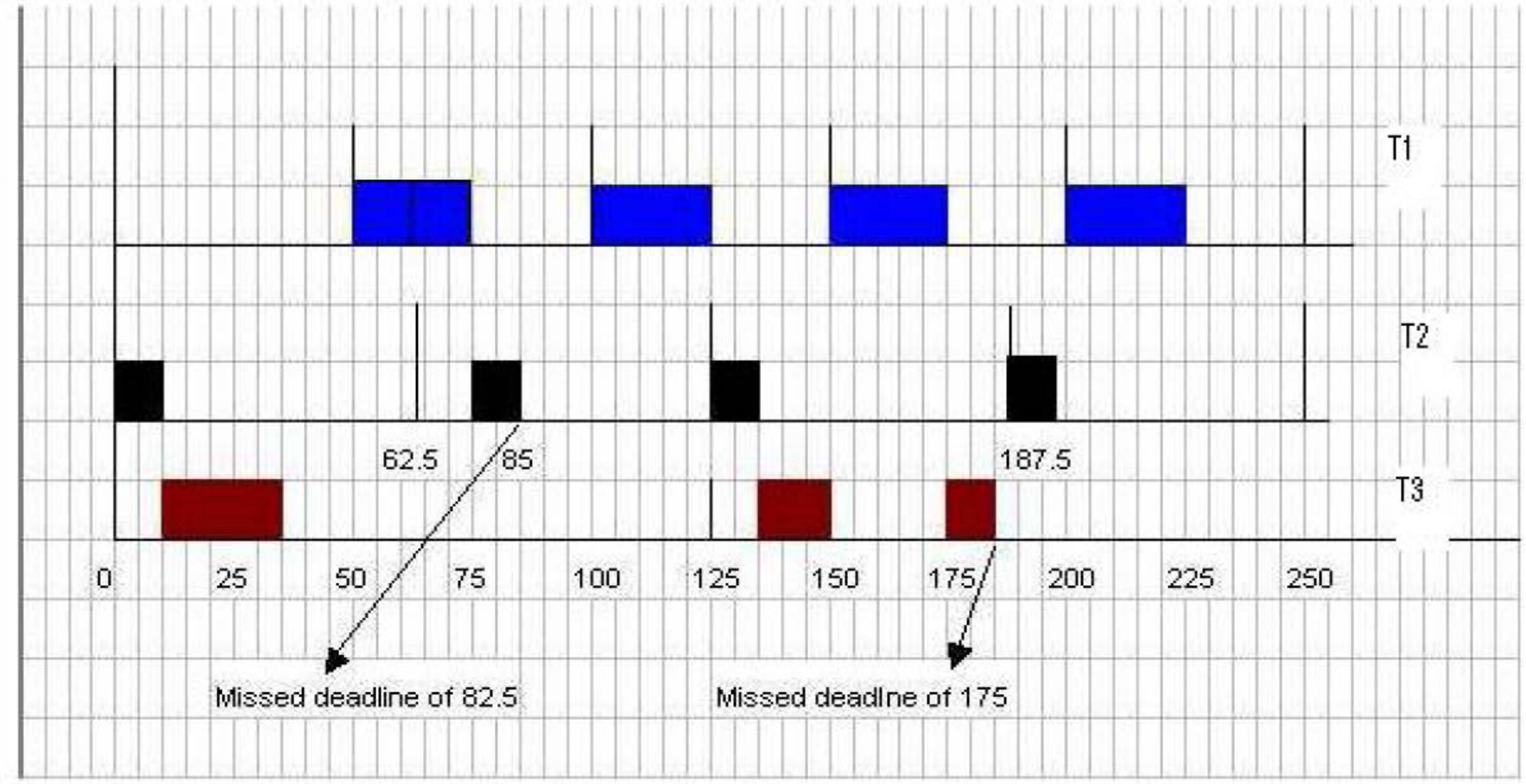
The schedule is:
T1,T2,T2,T3,T3,T1,T3,T3,T2,T2,T1,T3,T3,T3,T3,T1,T2,T2,Idle,Idle,T1,Idle,T3,T3,T2,T1,T2,T3,T3,Idle,T1,….

Deadline Monotonic (DM) Algorithm

- Another fixed priority scheduler
- Priorities are based on relative deadlines: shorter the deadline, higher the priority
- If every task has the period equal to relative deadline, same as RM
- For arbitrary deadlines, DM algorithm performs better than RM algorithm
- It may sometimes produce a feasible schedule when RM fails
- RM algorithm always fails if DM algorithm fails.

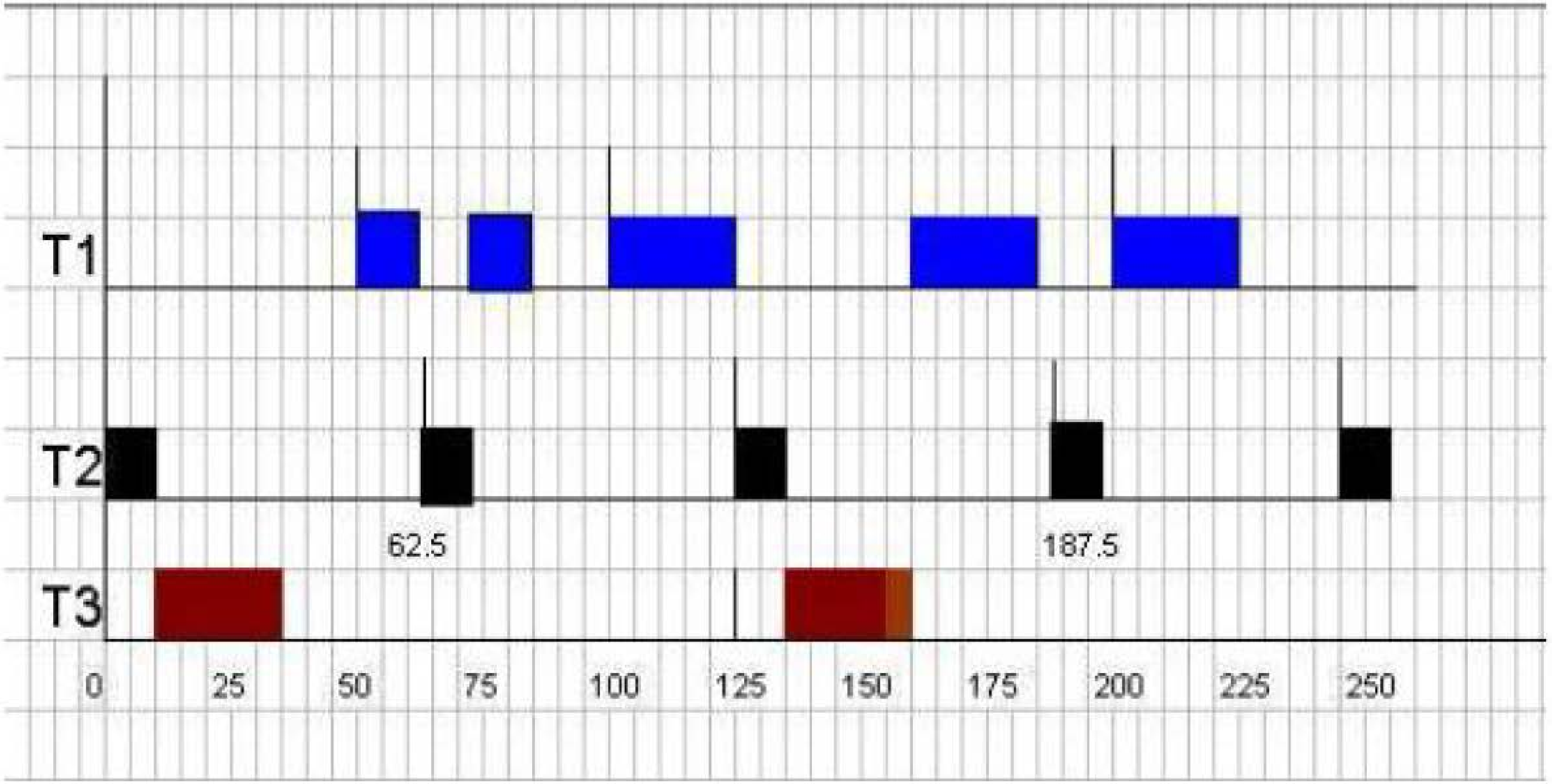
Example: DM v.s. RM

Using RM to schedule T1(50; 50; 25; 100); T2(0; 62.5; 10; 20); T3(0; 125; 25; 50)



Example: DM v.s. RM

Using DM to schedule T1(50; 50; 25; 100); T2(0; 62.5; 10; 20); T3(0; 125; 25; 50)



Dynamic-priority Scheduling: Earliest-deadline First (EDF)

- In this algorithm the task priorities are not fixed but change depending upon the closeness of their absolute deadlines.
- The processor always executes the task whose absolute deadline is the earliest. (Note that the absolute deadline is the arrival time of a task plus its relative deadline).
- If more than one tasks have the same absolute deadlines, EDF randomly selects one for execution next.

Example

- T1(5,2) and T2(7,4)

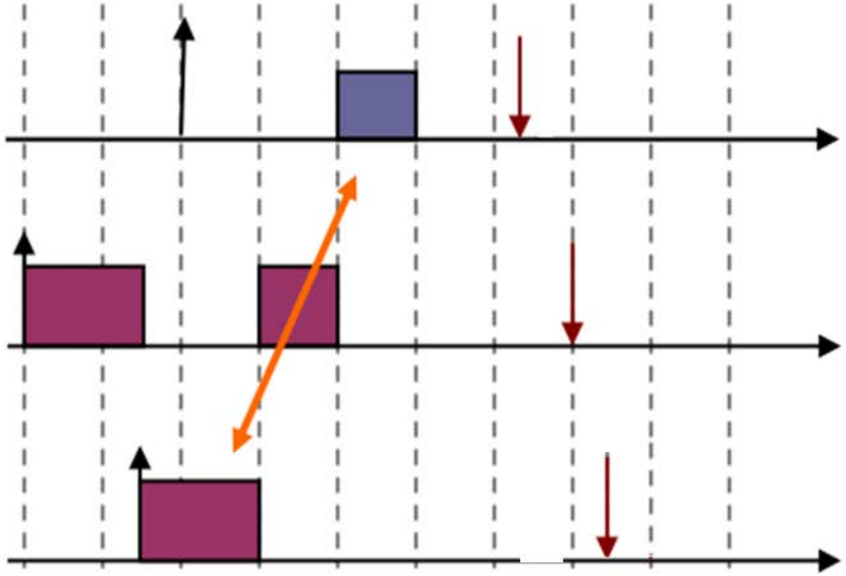
- By RM or DM: the scheduling is T1, T1, T2, T2, T2, T1, T1, deadline missed for Task 2!

- By EDF: T1, T1, T2, T2, T2, T2, T1, T1, T2, T2, T2, T2, T1, T1, T2, T1, T1,T2, T2, T2, T1, T1, T2, T2, T2, T2, T1,T1 …

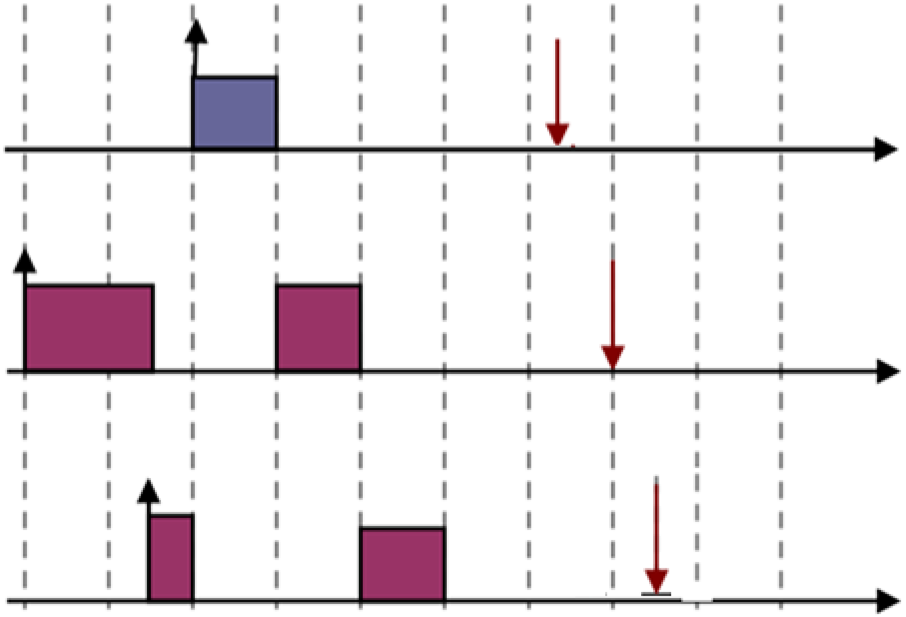
EDF Is Optimal

EDF is an optimal uniprocessor scheduling algorithm, which means that if EDF cannot feasibly schedule a task set on a uniprocessor, there is no other scheduling algorithm that can.

Why EDF Is Optimal?



if left side is feasible
→ so is the right side



EDF Schedulability Tests

- Test 1: (sufficient and necessary condition) A set of n periodic tasks, each of whose relative deadline is equal to or greater than its period, can be feasibly scheduled by EDF iff

$$\sum_{i=1}^{n} \left({}^{e_i}/_{p_i} \right) \leq 1$$

- Test 2: No simple test is available in the case where the relative deadlines are not equal to or greater than their periods. In such cases the best course of action is to develop a schedule using EDF algorithm to see if all deadlines are met over a given interval of time.

EDF Schedulability Tests (continued)

- A sufficient condition for such cases is:

$$\sum_{i=1}^{n} \left(e_i / \min(D_i, p_i) \right) \leq 1$$

- Only sufficient condition - if it fails, the task set may or may not be EDF schedulable.
- If Di $\geq$ pi, it reduces to the Test1 above.
- If Di < pi, the equation represents only a sufficient condition.

Comparison of RM and EDF Algorithms

- EDF is more flexible and has a better utilization than RM.

- Timing behaviour of a system scheduled with RM algorithm is more predictable.
  - In case of overload RM is stable in the presence of missed deadlines: same lower priority tasks miss the deadlines every time and there is no effect on higher priority tasks.
  - In case of EDF, it is difficult to predict which tasks will miss their deadlines during overloads. Also note that a late task that has already missed its deadline has a higher priority than a task whose deadline is still in the future.

Example

- T1(3,2) and T2(5,2)

- Assume that at t=2, a one-time emergent task is released, and the execution time for the emergent task is 2.
  - Using RM/DM, T1 will meet the deadline, and T2 will miss the deadline.

    - RM/DM: T1, T1, Em, Em, T1, T1, T1, T1, T2, T1, T1 (T2 missed deadline and T1 meet the deadline)

  - Using EDF, T1 and T2 will both miss deadline in the next cycle.

    - EDF: T1, T1, Em, Em, <u>T2</u>, <u>T1</u>, …