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Example: scheduling using EDF

Problem: Assume a system with tasks according to the figure below. The timing properties of the tasks are given in the table.

a) Determine, by analyzing the processor demand, whether the tasks are schedulable or not using EDF.

b) Determine, by using simulation, whether the tasks are schedulable or not using EDF.

Task	C_i	D_i	T_i
τ_1	2	3	4
τ_2	2	7	8
τ_3	3	12	16

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a) Determine the LCM for the tasks:

$$\text{LCM}\{T_1, T_2, T_3\} = \text{LCM}\{4, 8, 16\} = 16$$

Determine the control points K:

$$K_1 = \{D_1^k \mid D_1^k = kT_1 + D_1,\ D_1^k \le 16,\ k = 0,1,2,3\} = \{3,7,11,15\}$$
$$K_2 = \{D_2^k \mid D_2^k = kT_2 + D_2,\ D_2^k \le 16,\ k = 0,1\} = \{7,15\}$$
$$K_3 = \{D_3^k \mid D_3^k = kT_3 + D_3,\ D_3^k \le 16,\ k = 0\} = \{12\}$$

The processor demand must be checked at the following time points:

$$K = K_1 \cup K_2 \cup K_3 = \{3,7,11,12,15\}$$

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Example: scheduling using EDF

We define a table and examine every control point:

L	$N_1^L \cdot C_1$	$N_2^L \cdot C_2$	$N_3^L \cdot C_3$	$C_P(0,L)$	$C_P(0,L) \le L$
3	$\left(\left\lfloor \frac{3-3}{4} \right\rfloor + 1\right) \cdot 2 = 2$	$\left(\left\lfloor \frac{3-7}{8} \right\rfloor + 1\right) \cdot 2 = 0$	$\left(\left\lfloor \frac{3-12}{16} \right\rfloor + 1\right) \cdot 3 = 0$	2	OK!
7	$\left(\left\lfloor \frac{7-3}{4} \right\rfloor + 1\right) \cdot 2 = 4$	$\left(\left\lfloor \frac{7-7}{8} \right\rfloor + 1\right) \cdot 2 = 2$	$\left(\left\lfloor \frac{7-12}{16} \right\rfloor + 1\right) \cdot 3 = 0$	6	OK!
11	$\left(\left\lfloor \frac{11-3}{4} \right\rfloor + 1\right) \cdot 2 = 6$	$\left(\left\lfloor \frac{11-7}{8} \right\rfloor + 1\right) \cdot 2 = 2$	$\left(\left\lfloor \frac{11-12}{16} \right\rfloor + 1\right) \cdot 3 = 0$	8	OK!
12	$\left(\left\lfloor \frac{12-3}{4} \right\rfloor + 1\right) \cdot 2 = 6$	$\left(\left\lfloor \frac{12-7}{8} \right\rfloor + 1\right) \cdot 2 = 2$	$\left(\left\lfloor \frac{12-12}{16} \right\rfloor + 1\right) \cdot 3 = 3$	11	OK!
15	$\left(\left\lfloor \frac{15-3}{4} \right\rfloor + 1\right) \cdot 2 = 8$	$\left(\left\lfloor \frac{15-7}{8} \right\rfloor + 1\right) \cdot 2 = 4$	$\left(\left\lfloor \frac{15-12}{16} \right\rfloor + 1\right) \cdot 3 = 3$	15	OK!

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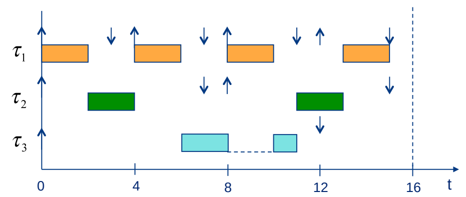
b) Simulate the execution of the tasks:



The tasks meet their deadlines also in this case!

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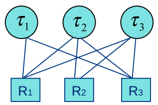
Example: scheduling using EDF

Problem: Assume a system with tasks according to the figure below.
The timing properties of the tasks are given in the table.
Three resources R1, R2 and R3 have three, one, and three units available, respectively.
The parameters H_{R1}, H_{R2} and H_{R3} represent the longest time a task may use the corresponding resource.
The parameters μ_{R1}, μ_{R2} and μ_{R3} represent the number of units a task requests from the corresponding resource.



Task	C_i	D_i	T_i	H_{R1}	H_{R2}	H_{R3}	μ_{R1}	μ_{R2}	μ_{R3}
τ_1	6	10	50	2	-	2	1	-	1
τ_2	7	17	50	1	2	2	2	1	3
τ_3	10	25	50	2	3	2	3	1	1

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Example: scheduling using EDF

Problem: (cont'd)
Task τ_1 first requests R3 and then, while using R3, requests R1
Task τ_2 first requests R3 and then, while using R3, requests R2; then, after releasing the two resources, τ_2 requests R1
Task τ_3 first requests R2 and then, while using R2, requests R1; then, after releasing the two resources, τ_3 requests R3

Examine the schedulability of the tasks when the SRP (Stack Resource Policy) protocol is used.
a) Derive the ceilings (dynamic and worst-case) of the resources.
b) Derive the blocking factors for the tasks.
c) Show whether the tasks are schedulable or not.

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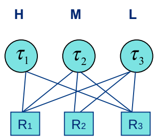
Example: scheduling using EDF

a) Preemption levels of the tasks:



$\pi_1 = H$ (τ_1 has the shortest relative deadline)
$\pi_2 = M$
$\pi_3 = L$ (τ_3 has the longest relative deadline)

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Example: scheduling using EDF

Resource ceiling $C_R(a)$ as a function of available units a:

($C_R(0)$ is the worst-case ceiling used for calculating blocking factors)

	$C_R(3)$	$C_R(2)$	$C_R(1)$	$C_R(0)$
R_1	0	L τ_1 uses τ_3 may block	L τ_2 uses τ_3 may block	H τ_3 uses τ_1 may block
R_2	-	-	0	M τ_3 uses τ_2 may block
R_3	0	M τ_1 or τ_3 use τ_2 may block	M τ_1 and τ_3 use τ_2 may block	H τ_2 uses τ_1 may block

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Example: scheduling using EDF

b) Observe that nested blocking is used by all tasks. This could lead to accumulated critical region blocking times in the final blocking factor.

τ_1

- $Wait(R_3,1)$ H
- $Wait(R_1,1)$ H
- ⋮
- $Signal(R_1)$ H
- $Signal(R_3)$ H

τ_2

- $Wait(R_3,3)$ H
- $Wait(R_2,1)$ M
- ⋮
- $Signal(R_2)$ M
- $Signal(R_3)$ H
- ⋮
- $Wait(R_1,2)$ H
- ⋮
- $Signal(R_1)$ H

τ_3

- $Wait(R_2,1)$ M
- $Wait(R_1,3)$ H
- ⋮
- $Signal(R_1)$ H
- $Signal(R_2)$ M
- ⋮
- $Wait(R_3,1)$ H
- ⋮
- $Signal(R_3)$ H

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Blocking factors for the tasks:

$$B_1 = \max\{1,4,2,2\} = 4$$

(τ_2 uses R_1; τ_2 uses R_3 incl. nested use of R_2; τ_3 uses R_3; τ_3 uses R_1)

$$B_2 = \max\{2,5\} = 5$$

(τ_3 uses R_3; τ_3 uses R_2 incl. nested use of R_1)

$$B_3 = 0$$

τ_3 has lowest preemption level, and cannot be blocked

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c) Determine the LCM for the tasks:

$$\text{LCM}\{T_1,T_2,T_3\} = \text{LCM}\{50,50,50\} = 50$$

Determine the control points K:

$$K_1 = \{D_1^k \mid D_1^k = kT_1 + D_1,\ D_1^k \le 50,\ k = 0\} = \{10\}$$
$$K_2 = \{D_2^k \mid D_2^k = kT_2 + D_2,\ D_2^k \le 50,\ k = 0\} = \{17\}$$
$$K_3 = \{D_3^k \mid D_3^k = kT_3 + D_3,\ D_3^k \le 50,\ k = 0\} = \{25\}$$

The processor demand must be checked at the following time points:

$$K = K_1 \cup K_2 \cup K_3 = \{10,17,25\}$$

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Example: scheduling using EDF

Processor demand calculations for each task:

$$C_P^1 = \left(\left\lfloor \frac{L-D_1}{T_1} \right\rfloor + 1\right) C_1 + \left(\left\lfloor \frac{L-D_1}{T_1} \right\rfloor + 1\right) B_1$$

$$C_P^2 = \left(\left\lfloor \frac{L-D_1}{T_1} \right\rfloor + 1\right) C_1 + \left(\left\lfloor \frac{L-D_2}{T_2} \right\rfloor + 1\right) C_2 + \left(\left\lfloor \frac{L-D_2}{T_2} \right\rfloor + 1\right) B_2$$

$$C_P^3 = \left(\left\lfloor \frac{L-D_1}{T_1} \right\rfloor + 1\right) C_1 + \left(\left\lfloor \frac{L-D_2}{T_2} \right\rfloor + 1\right) C_2 + \left(\left\lfloor \frac{L-D_3}{T_3} \right\rfloor + 1\right) C_3 + \left(\left\lfloor \frac{L-D_3}{T_3} \right\rfloor + 1\right) B_3 =$$
$$= \{B_3 = 0\} = \left(\left\lfloor \frac{L-D_1}{T_1} \right\rfloor + 1\right) C_1 + \left(\left\lfloor \frac{L-D_2}{T_2} \right\rfloor + 1\right) C_2 + \left(\left\lfloor \frac{L-D_3}{T_3} \right\rfloor + 1\right) C_3$$

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Example: scheduling using EDF

We define a table and examine every control point:

$C_P^2(0,17) > 17$ (FAIL!)

L	$C_P^1(0,L)$	$C_P^2(0,L)$	$C_P^3(0,L)$
10	$\left(\left\lfloor \frac{10-10}{50} \right\rfloor + 1\right)6 + \left(\left\lfloor \frac{10-10}{50} \right\rfloor + 1\right)4 = 6 + 4 = 10$	$\left(\left\lfloor \frac{10-10}{50} \right\rfloor + 1\right)6 + \left(\left\lfloor \frac{10-17}{50} \right\rfloor + 1\right)7 + \left(\left\lfloor \frac{10-17}{50} \right\rfloor + 1\right)5 = 6 + 0 + 0 = 6$	$\left(\left\lfloor \frac{10-10}{50} \right\rfloor + 1\right)6 + \left(\left\lfloor \frac{10-17}{50} \right\rfloor + 1\right)7 + \left(\left\lfloor \frac{10-25}{50} \right\rfloor + 1\right)10 = 6 + 0 + 0 = 6$
17	$\left(\left\lfloor \frac{17-10}{50} \right\rfloor + 1\right)6 + \left(\left\lfloor \frac{17-10}{50} \right\rfloor + 1\right)4 = 6 + 4 = 10$	$\left(\left\lfloor \frac{17-10}{50} \right\rfloor + 1\right)6 + \left(\left\lfloor \frac{17-17}{50} \right\rfloor + 1\right)7 + \left(\left\lfloor \frac{17-17}{50} \right\rfloor + 1\right)5 = 6 + 7 + 5 = 18$	$\left(\left\lfloor \frac{17-10}{50} \right\rfloor + 1\right)6 + \left(\left\lfloor \frac{17-17}{50} \right\rfloor + 1\right)7 + \left(\left\lfloor \frac{17-25}{50} \right\rfloor + 1\right)10 = 6 + 7 + 0 = 13$
25	$\left(\left\lfloor \frac{25-10}{50} \right\rfloor + 1\right)6 + \left(\left\lfloor \frac{25-10}{50} \right\rfloor + 1\right)4 = 6 + 4 = 10$	$\left(\left\lfloor \frac{25-10}{50} \right\rfloor + 1\right)6 + \left(\left\lfloor \frac{25-17}{50} \right\rfloor + 1\right)7 + \left(\left\lfloor \frac{25-17}{50} \right\rfloor + 1\right)5 = 6 + 7 + 5 = 18$	$\left(\left\lfloor \frac{25-10}{50} \right\rfloor + 1\right)6 + \left(\left\lfloor \frac{25-17}{50} \right\rfloor + 1\right)7 + \left(\left\lfloor \frac{25-25}{50} \right\rfloor + 1\right)10 = 6 + 7 + 10 = 23$