CSC 112: Computer Operating Systems
Lecture 6

Real-Time Scheduling
Exercises ANS

Department of Computer Science,

Hofstra University

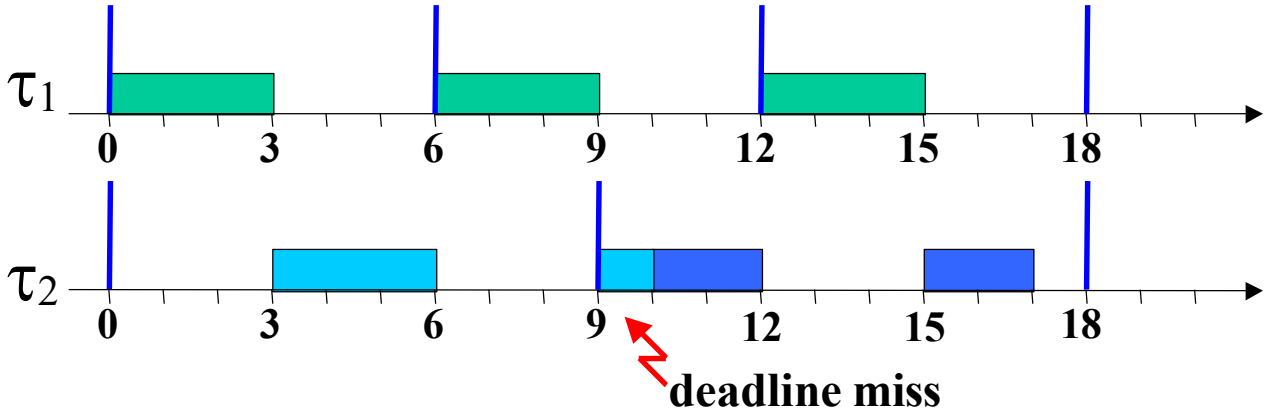
Q1. Schedulability under RM or EDF

- Determine schedulability of the following tasksets under (1) RM scheduling, using use Utilization Bound test and/or Response Time Analysis (RTA) to determine taskset schedulability. (2) EDF scheduling, using Utilization Bound test (the RM Utilization Bounds are provided in the following table). We use the notation $\tau_i\,(C_i, T_i, D_i)$ to denote task τ_i with WCET C_i Period T_i, Deadline D_i (c.f. Slide 33 in Lecture 6)
- 1) Taskset $\tau_1\,(3, 6, 6)$, $\tau_2\,(4, 9, 9)$
- 2) Taskset $\tau_1\,(3, 6, 6)$, $\tau_2\,(3, 9, 9)$
- 3) Taskset $\tau_1\,(3, 6, 6)$, $\tau_2\,(2, 9, 9)$
- 4) Taskset $\tau_1\,(2, 4, 4)$, $\tau_2\,(4, 8, 8)$

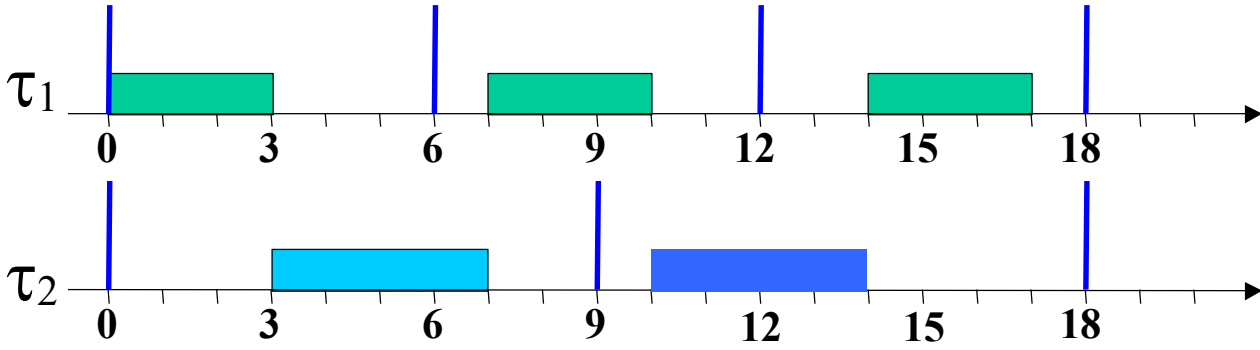
# Tasks	RM Util Bound
1	1.00
2	0.828
3	0.780

Q1. Schedulability under RM or EDF ANS

- 1) Taskset $\tau_1(3, 6, 6), \tau_2(4, 9, 9)$
- Total utilization $U = \frac{3}{6} + \frac{4}{9} = 0.944 > 0.828$. Since utilization exceeds the RM bound, we cannot determine its schedulability under RM, so we perform RTA analysis to compute WCRT of each task, by solving $R_i = C_i + \sum_{\forall j \in hp(i)} \left\lceil \frac{R_i}{T_j} \right\rceil C_j$
- For higher-priority (smaller period) task $\tau_1, R_1 = C_1 = 3 \leq D_1 = 6$, hence τ_1 is schedulable
- For lower-priority (larger period) task $\tau_2, R_2 = C_2 + \left\lceil \frac{R_2}{T_1} \right\rceil C_1 = 4 + \left\lceil \frac{R_2}{6} \right\rceil \cdot 3$, solving it iteratively gives $R_2 = 10 > D_2 = 9$, hence τ_2 is not schedulable
- We determine this taskset to be not schedulable under RM.
- Total utilization $U = \frac{3}{6} + \frac{4}{9} = 0.944 \leq 1$, hence we determine this taskset to be schedulable under EDF
- (You are not required to draw the Gantt charts below, they are FYI only.)



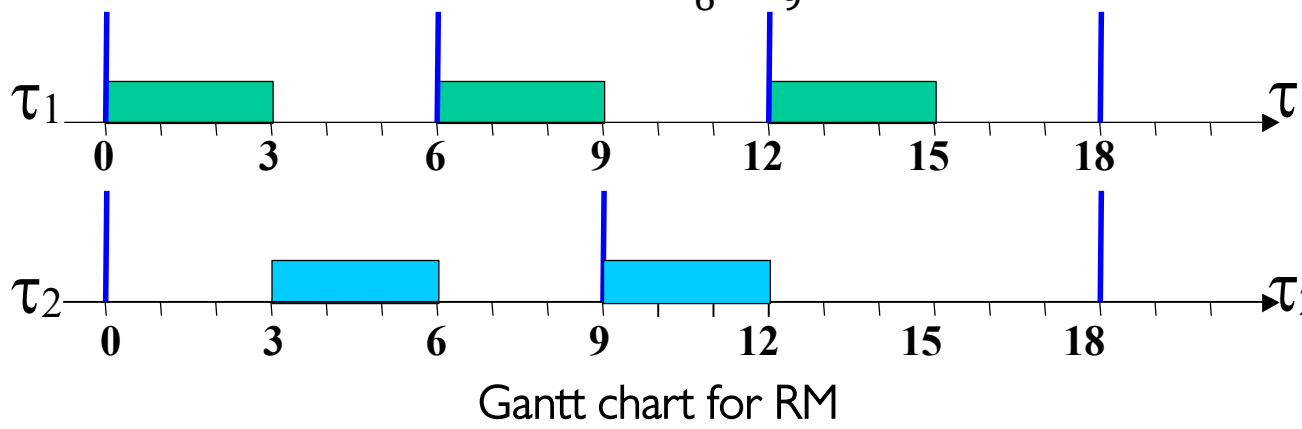
Gantt chart for RM



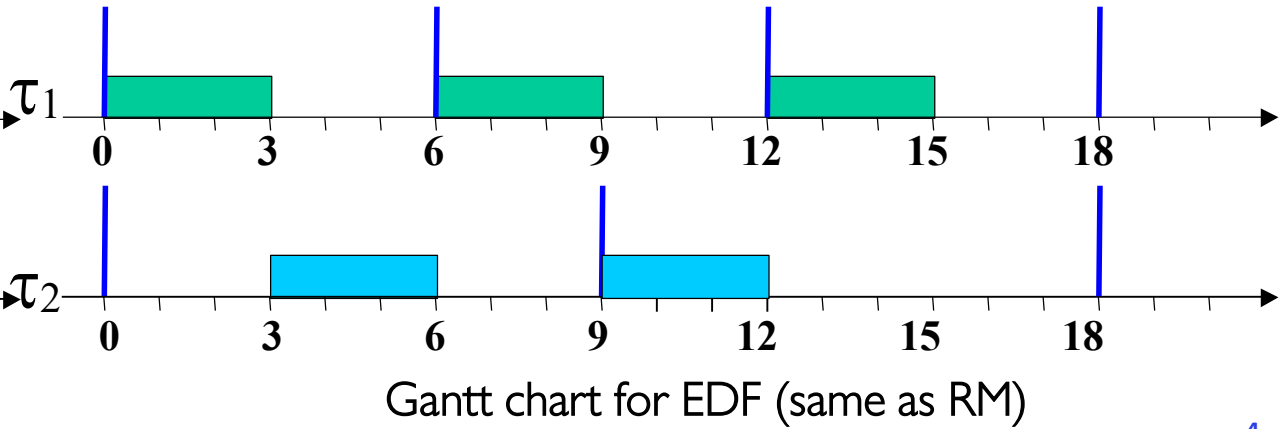
Gantt chart for EDF

Q1. Schedulability under RM or EDF ANS

- 2) Taskset $\tau_1(3, 6, 6), \tau_2(3, 9, 9)$
- Total utilization $U = \frac{3}{6} + \frac{3}{9} = 0.833 > 0.828$. Since utilization exceeds the RM bound, we cannot determine its schedulability under RM, so we perform RTA analysis to compute WCRT of each task, by solving $R_i = C_i + \sum_{\forall j \in hp(i)} \left\lceil \frac{R_i}{T_j} \right\rceil C_j$
- For higher-priority (smaller period) task $\tau_1, R_1 = C_1 = 3 \leq D_1 = 6$, hence τ_1 is schedulable
- For lower-priority (larger period) task $\tau_2, R_2 = C_2 + \left\lceil \frac{R_2}{T_1} \right\rceil C_1 = 3 + \left\lceil \frac{R_2}{6} \right\rceil \cdot 3,$ solving it iteratively gives $R_2 = 9 \leq D_2 = 9$, hence τ_2 is schedulable
  - Even though Gantt chart shows $R_2 = 6$, the ceiling operator counts 2 preemptions by task τ_1 to task τ_2, since τ_2 may be a small remaining ϵ execution time at time 6 for it to experience 1 more pre-emption by task τ_1
- We determine this taskset to be schedulable under RM.
- Total utilization $U = \frac{3}{6} + \frac{4}{9} = 0.833 \leq 1$, hence we determine this taskset to be schedulable under EDF



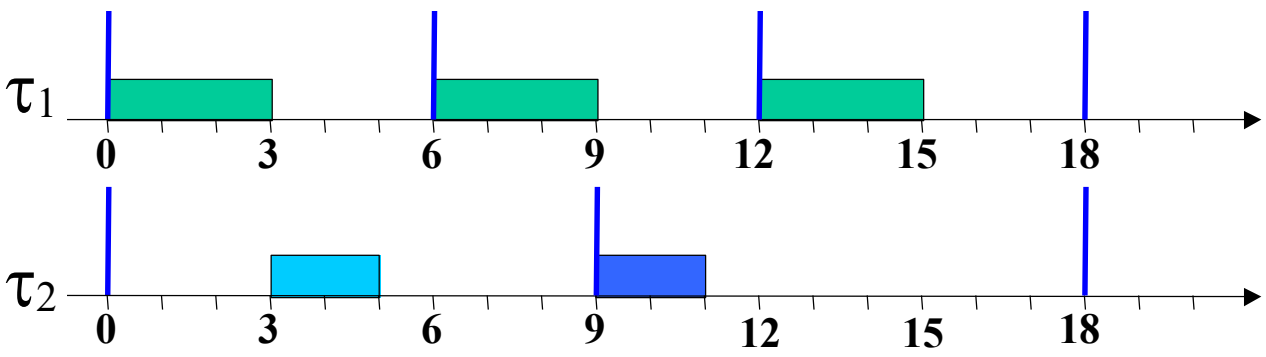
Gantt chart for RM



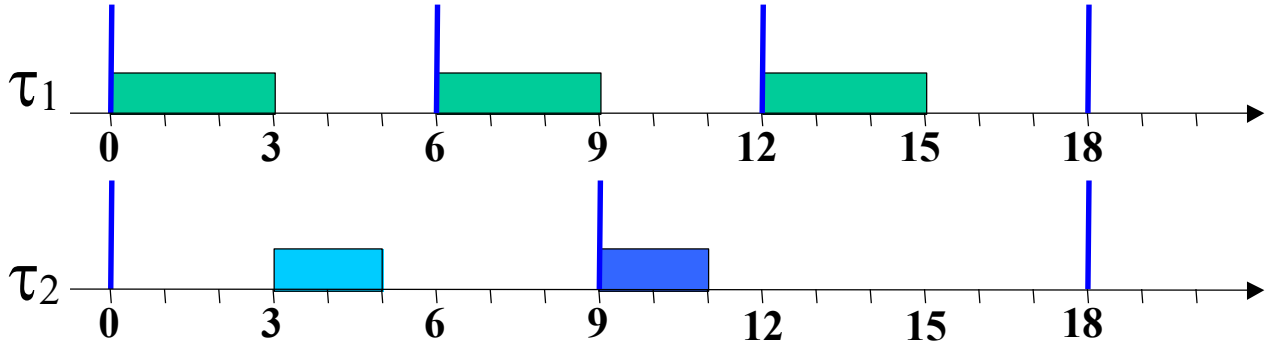
Gantt chart for EDF (same as RM)

Q1. Schedulability under RM or EDF ANS

- 3) Taskset $\tau_1(3, 6, 6), \tau_2(2, 9, 9)$
- Total utilization $U = \frac{3}{6} + \frac{2}{9} = 0.722 \leq 0.828$. Since utilization is within the RM bound, we determine this taskset to be schedulable under RM, without the need for RTA analysis
- Total utilization $U = \frac{3}{6} + \frac{4}{9} = 0.833 \leq 1$, hence we determine this taskset to be schedulable under EDF



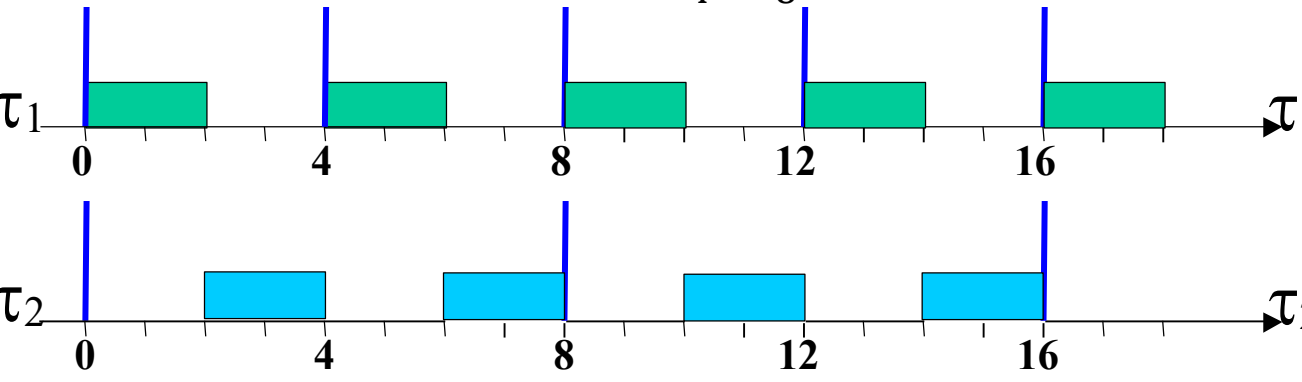
Gantt chart for RM



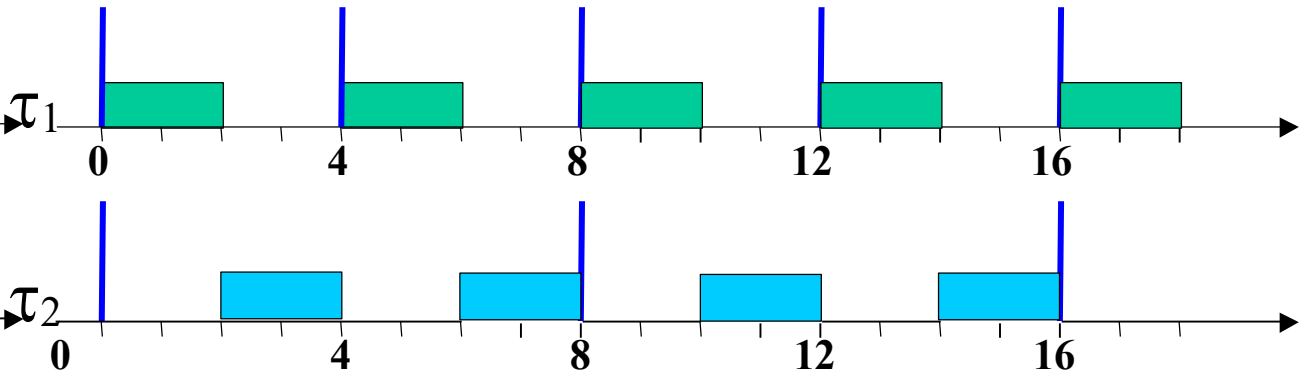
Gantt chart for EDF (same as RM)

Q1. Schedulability under RM or EDF ANS

- 4) Taskset $\tau_1\,(2, 4, 4), \tau_2\,(4, 8, 8)$
- Total utilization $U = \frac{2}{4} + \frac{4}{8} = 1.0 > 0.828$. Since utilization exceeds the RM bound, we cannot determine its schedulability under RM, so we perform RTA analysis to compute WCRT of each task, by solving $R_i = C_i + \sum_{\forall j \in hp(i)} \left\lceil \frac{R_i}{T_j} \right\rceil C_j$
- For higher-priority (smaller period) task $\tau_1, R_1 = C_1 = 2 \leq D_1 = 4$, hence τ_1 is schedulable
- For lower-priority (larger period) task $\tau_2, R_2 = C_2 + \left\lceil \frac{R_2}{T_1} \right\rceil C_1 = 4 + \left\lceil \frac{R_2}{4} \right\rceil \cdot 2,$ solving it iteratively gives $R_2 = 8 \leq D_2 = 8$, hence τ_2 is schedulable
- We determine this taskset to be schedulable under RM.
  - We can also skip RTA, and use this condition to this taskset to be schedulable under RM. "If periods are harmonic (larger periods divisible by smaller periods), then utilization bound is 1."
- Total utilization $U = \frac{2}{4} + \frac{4}{8} = 1.0 \leq 1$, hence we determine this taskset to be schedulable under EDF



Gantt chart for RM



Gantt chart for EDF (same as RM)

Q2 RM, EDF, LLF

- Consider the set of 2 periodic tasks whose period, deadline and WCET parameters are given.
- 1. For each scheduling algorithm (RM, EDF, LLF), draw the Gantt chart by filling in the table with the task ID that runs in each time slot until time 10, and calculate the WCRT for each task.
- 2. Under RM scheduling, use utilization bound and Response Time Analysis (RTA) to determine taskset schedulability.

Task ID	T=D	C	RM Resp. Time	EDF Resp. Time	LLF Resp. Time
1	8	3			
2	10	4			

RM										
EDF										
LLF										
Time	0	1	2	3	4	5	6	7	8	9	10

Gantt Chart

Time	T_1 Laxity	T_2 Laxity	Running Task
t=0			
t=1			
t=2			
t=3			
t=4			
t=5			
t=6			
t=7			
t=8			
T=9			

Q2 RM, EDF, LLF ANS

- Consider the set of 2 periodic tasks whose period, deadline and WCET parameters are given.
- 1. For each scheduling algorithm (RM, EDF, LLF), draw the Gantt chart by filling in the table with the task ID that runs in each time slot until time 10, and calculate the WCRT for each task.
- 2. Under RM scheduling, determine taskset schedulability using utilization bound and/or Response Time Analysis (RTA) to

Task ID	T=D	C	RM Resp. Time	EDF Resp. Time	LLF Resp. Time
1	8	3	3	3	5
2	10	4	7	7	7

RM	1	1	1	2	2	2	2	X	1	1
EDF	1	1	1	2	2	2	2	X	1	1
LLF	1	1	2	2	1	2	2	X	1	1

Time 0 1 2 3 4 5 6 7 8 9 10

Gantt Chart

Time	T_1 Laxity	T_2 Laxity	Running Task
t=0	8-0-3=5	10-0-4=6	1
t=1	8-1-2=5	10-1-4=5	1 (tie)
t=2	8-2-1=5	10-2-4=4	2
t=3	8-3-1=4	10-3-3=4	2 (tie)
t=4	8-4-1=3	10-4-2=4	1
t=5	T1 done	10-5-2=3	2
t=6	T1 done	10-6-1=3	2
t=7	T1 done	T2 done	X
t=8	16-8-3=5	T2 done	1
T=9	16-9-2=5	T2 done	1

Q2 RM, EDF, LLF ANS

- Total utilization $U = \frac{3}{8} + \frac{4}{10} = 0.775 \leq 0.828$. Since utilization is within the RM bound, we determine this taskset to be schedulable under RM, without the need for RTA analysis
- Total utilization $U = \frac{3}{8} + \frac{4}{10} = 0.775 \leq 1.0$, hence we determine this taskset to be schedulable under EDF and LLF