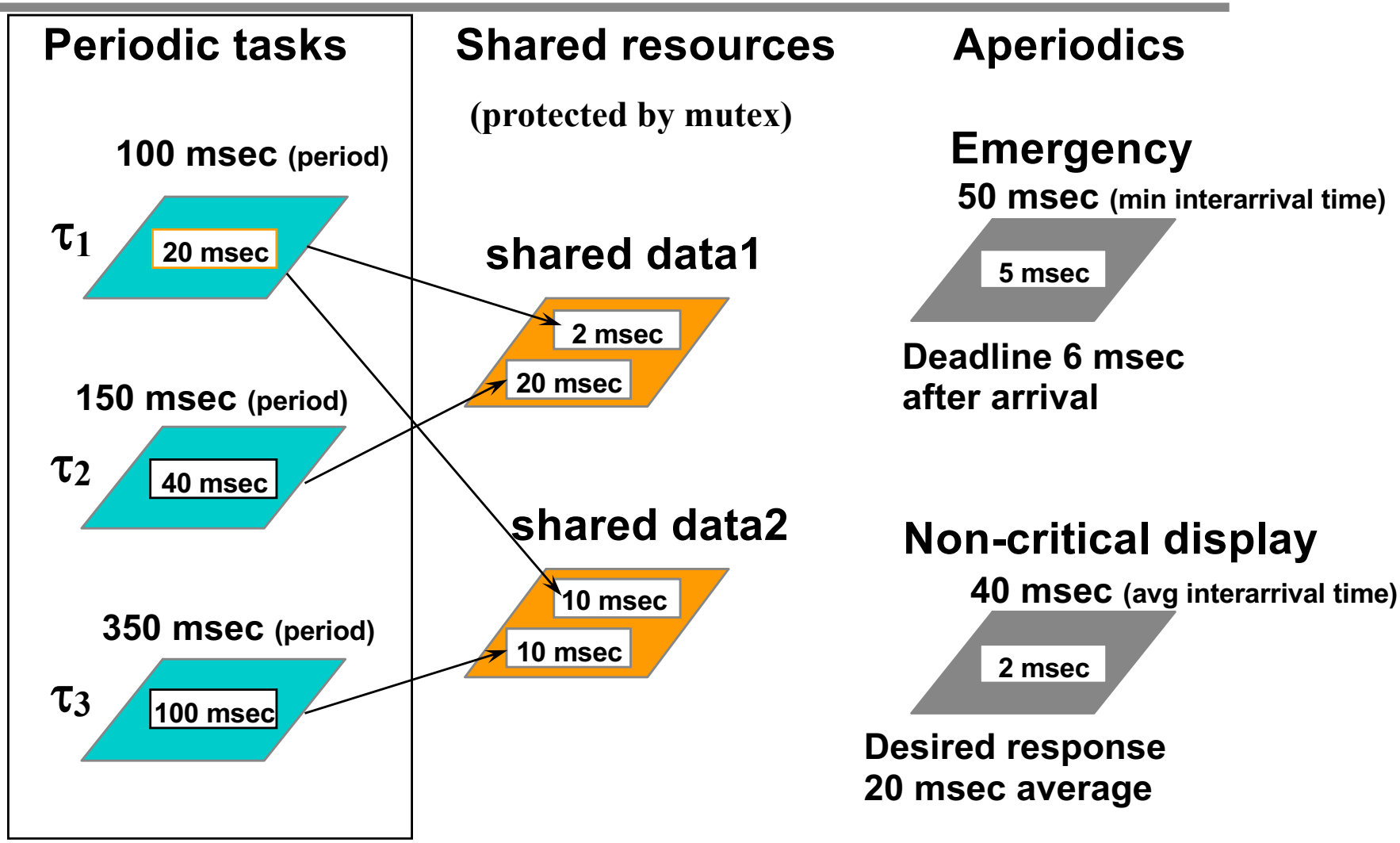
Overview

- Today: this lecture focuses on a comprehensive task set scheduling scenario with real-time periodic and aperiodic tasks together with resource sharing.
- **Goal**: Test at design time, and off-line if the task set is schedulable!

- **Note**: some sample questions in preparation for the exam have been posted (with solutions). Notice that Question 3 (Posix Signals) uses a primitive (sigaction) that has not been explained in class. As such, it is not expected that you are able to fully solve that question; however, it is included in the sample questions to show an example of how a code question might look like in the exam.

- **Exam policy:**
- You may use one A4 double-sided handwritten cheat sheet and a scientific calculator. You have exactly 3 hours to complete the exam. You cannot use any book during the exam.

A Sample Problem



Goal: guarantee that no real-time deadline is missed!!!

Schedulability analysis of sample problem

- According to the sample problem of previous slide, we can identify the following task set:
- ???

Schedulability analysis of sample problem

- According to the sample problem of previous slide, we can identify the following task set:
  - SS_{hard} ➔ Sporadic Server to schedule the hard aperiodic activity
  - SS_{soft} ➔ Sporadic Server to schedule the soft aperiodic activity (We have chosen a server with budget C=10 and period P=100; we need to verify if our choice is correct!)
  - T1, T2, T3 ➔ hard periodic tasks

	C	P	B	D
SS_{hard}	5	50	?	6
SS_{soft}	10	100	?	100
T_1	20	100	?	100
T_2	40	150	?	150
T_3	100	350	?	350

Schedulability analysis of sample problem

- SS_{soft} ➔ Sporadic Server to schedule the soft aperiodic activity
  - we have chosen a server with budget C=10 and period P=100;
  - we need to verify if our choice is correct.
  - Let's check the average response time of soft aperiodic by using M/M/1 queueing theory:

$$w = (1/\mu)/(1 - \rho)$$

Schedulability analysis of sample problem

- SS_{soft} ➔ Sporadic Server to schedule the soft aperiodic activity
  - we have chosen a server with budget C=10 and period P=100;
  - we need to verify if our choice is correct.
  - Let's check the average response time of soft aperiodic by using M/M/1 queueing theory:
- **Queuing theory using M/M/1 approximation indicates that the average response time is 4 msec.**

- **The server_bandwidth:** **10/100 = 0.1**
- **The CPU_workload:** **2/40 = 0.05**
- **Server_workload:** **0.05/0.1 = 0.5**

- **The average response time:** $w = (1/\mu)/(1 - \rho)$

  (Average Execution Time) / (1 – Server_workload)
  = 2 / (1 – 0.5) = 4 msec

Schedulability analysis of sample problem

- Let's first identify the blocking times of each task by assuming to use PCP:

	SD1	SD2
SS_{hard}	0	0
SS_{soft}	0	0
T_1	2	10
T_2	20	0
T_3	0	10

$$B_i = \max_{j,k}[D_{j,k} \mid prio_j < prio_i, \quad C(S_k) \geq prio_i]$$

Schedulability analysis of sample problem

- Let's first identify the blocking times of each task by assuming to use PCP:

	SD1	SD2
SS_{hard}	0	0
SS_{soft}	0	0
T_1	2	10
T_2	20	0
T_3	0	10

Ceil(SD1)=1/100

Ceil(SD2)=1/100

$$B_i = \max_{j,k}[D_{j,k} \mid prio_j < prio_i, \quad C(S_k) \geq prio_i]$$

$$B_{SS\_hard} = 0$$

$$B_{SS\_soft} = \max(10,20) = 20$$

$$B_{T1} = \max(10,20) = 20$$

$$B_{T2} = 10$$

$$B_{T3} = 0$$

Schedulability analysis of sample problem

- We can now check the schedulability of the all task set by using UB & Exact Analysis:

	C	P	B	D
SS_{hard}	5	50	0	6
SS_{soft}	10	100	20	100
T_1	20	100	20	100
T_2	40	150	10	150
T_3	100	350	0	350

Schedulability analysis of sample problem

- We can now check the schedulability of the all task set by using UB & Exact Analysis:

	C	P	B	D
SS_{hard}	5	50	0	6
SS_{soft}	10	100	20	100
T_1	20	100	20	100
T_2	40	150	10	150
T_3	100	350	0	350

SS_{hard} $\frac{5+44}{50} < U(1) = 1$ OK!

SS_{soft} $\frac{5}{50}+\frac{10}{100}+\frac{20}{100}+\frac{20}{100} = 0.6 < U(3) = 0.779$ OK!

τ_1 $\frac{5}{50}+\frac{10}{100}+\frac{20}{100}+\frac{20}{100} = 0.6 < U(3) = 0.779$ OK!

τ_2 $\frac{5}{50}+\frac{10}{100}+\frac{20}{100}+\frac{40}{150}+\frac{10}{150} = 0.734 < U(4) = 0.756$ OK!

τ_3 $\frac{5}{50}+\frac{10}{100}+\frac{20}{100}+\frac{40}{150}+\frac{100}{350} = 0.953 > U(5) = 0.756$ FAILED! ➔ use exact analysis

Schedulability analysis of sample problem

- We can now check the schedulability of the all task set by using UB & Exact Analysis:

	C	P	B	D
SS_{hard}	5	50	0	6
SS_{soft}	10	100	20	100
T_1	20	100	20	100
T_2	40	150	10	150
T_3	100	350	0	350

$$5+10+20+40+100=175$$

$$100+\left\lceil\frac{175}{50}\right\rceil 5+\left\lceil\frac{175}{100}\right\rceil 10+\left\lceil\frac{175}{100}\right\rceil 20+\left\lceil\frac{175}{150}\right\rceil 40=100+20+20+40+80=260$$

$$100+\left\lceil\frac{260}{50}\right\rceil 5+\left\lceil\frac{260}{100}\right\rceil 10+\left\lceil\frac{260}{100}\right\rceil 20+\left\lceil\frac{260}{150}\right\rceil 40=100+30+30+60+80=300$$

$$100+\left\lceil\frac{300}{50}\right\rceil 5+\left\lceil\frac{300}{100}\right\rceil 10+\left\lceil\frac{300}{100}\right\rceil 20+\left\lceil\frac{300}{150}\right\rceil 40=100+30+30+60+80=300<P_3$$

The task set is schedulable!!!