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Exercise for the lecture
Embedded Systems
Wintersemester 17/18

Written Exercise Sheet 1

Hints: These assignments will be discussed at E23, from 10:15 AM - 11:45 AM on 24. Oct. 2017. You are not obligated to turn in the solutions. Exception! We will organize to give you feedbacks.

1 Definition of Worst-Case Execution Time

For cyber-physical systems, it is important to know the maximum (worst-case) execution time of a program. How will you derive such an upper bound? Will there be some difficulties?

Solution: Computing the exact WCET of a problem is in general not possible (uncomputable for Turing machines), since all possible input sets, all possible initial and intermediate system states must be considered. Nevertheless, there exist several techniques to derive an upper bound, e.g., architecture analysis, program path analysis etc. However, the WCET strongly depends on multiple factors as, e.g., input parameters (algorithm parameters, problem size etc.), cache configuration and replacement policies, pipelines, scheduling, influences from the environment etc.

2 Power/Energy Consumption

You have at your disposal a battery with a capacity of 3600 mAh. Let us assume that its voltage is **constant** at 1.1 Volts until it is empty. Also, let us assume that we can ignore the power consumption of other electronic components.

Suppose that you have a CMOS system running with the capability of dynamic voltage frequency scaling. Assume that you can choose any frequency between 10 MHz and 200 MHz. The power consumption to operate at frequency f MHz is equal to $10^{-5}f^3 + 1$ mWatt. Suppose that you need to operate this system continuously with a constant frequency f^* until the battery gets empty. What is the maximum frequency f^* that can be chosen to ensure that the system can be operated consecutively for 360 hours?

Solution: 100 MHz

3 Time/Distance Diagrams

Draw a time/distance diagram to represent the cycles of H-Bahn Line 1 and Line 2. Please use the information from the figure, that is going to be valid for 2018. In this new program, the H-Bahn is extended to run from Emil-Figge-Str. to the Informatik building so that Informatikers do not need to walk for long distance to Mensa. one directions of Line 1 (one starts from Informatik and ein starts from Eichlinghofen) start at 10:11 und stay in every station for one minute. The Line 2 starts at the same time from Nordcampus and stays in each station for *half a minute*.

The departure plans are also found here:

Line 1 Nord-Süd **10:11** Informatik, **10:13** Technologiezentrum, **10:16** Universität S, **10:19** Campus Süd, **10:21** Eichlinghofen, **10:23** Campus Süd, ...

Line 1 Süd-Nord **10:11** Eichlinghofen, **10:13** Campus Süd, **10:16** Universität S, **10:19** Technologiezentrum, **10:21** Informatik, **10:23** Technologiezentrum, ...

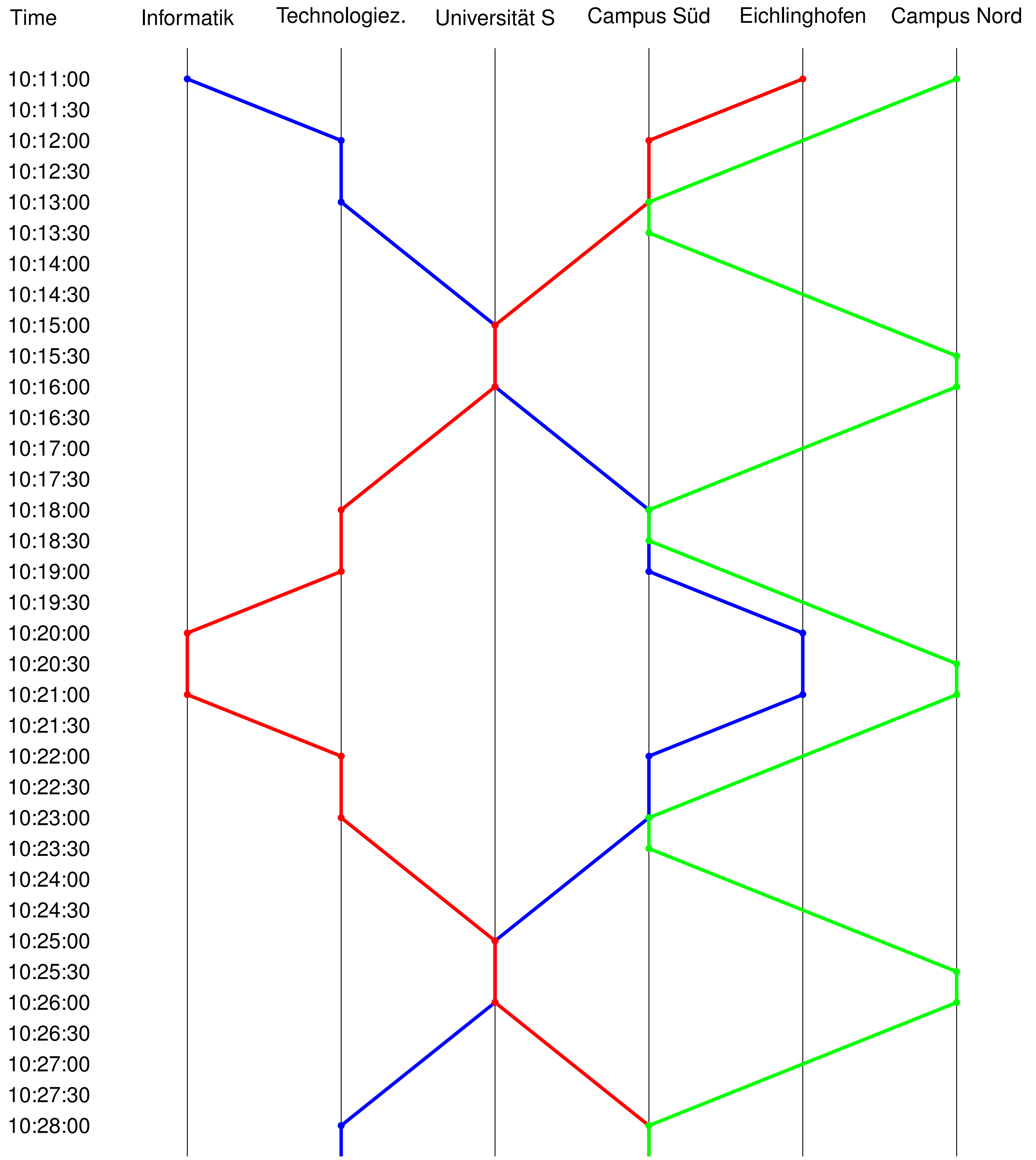
Line 2 **10:11:00** Campus Nord, **10:13:30** Campus Süd, **10:16:00** Campus Nord, **10:18:30** Campus Süd, ...

Informatik
1 min
Technologiezentrum
2 min
Universität S
2 min
Campus Süd
1 min
Eichlinghofen

Campus Nord
2 min
Campus Süd

Please draw the time/distance diagram.

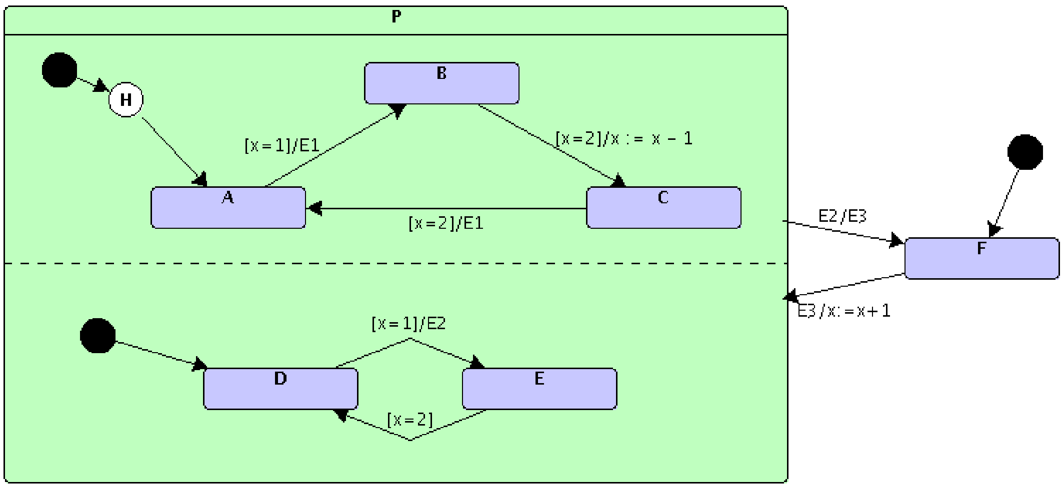
Solution:



4 StateCharts

Suppose that we have the following StateCharts Diagram:

Interpret the functions of the above StateCharts, when the event E3 generated at State F is $x = 0$. Please write down the configurations (active states, events, and the values of “x”) of the system after events are generated (till you can conclude the repetition.) Please also explain why the transition from E to D is not possible.



Solution:

	A	B	C	D	E	F	P	x
(reset)						x		0
E3	x			x		x	x	1
$[x=1]$		x			x		x	1
E1, E2						x		1
E3		x		x			x	2
	...	...	...	...	...	...	...	...

5 Multithreading

Suppose, the following code is given

```
semaphore S;
integer u;
```

```
thread a {
u = 3;              //op a1
if u<10             //op a2
   {u = u + 1; ..}  //op a3
else u=5;           //op a4
};
```

```
thread b {
u = 2;              //op b1
if u<4              //op b2
  {u = u + 4; ..}   //op b3
else u=10;          //op b4
};
```

- Each thread is supposed to be executed once on a microprocessor system.
- Threads can be executed in any sequence and the execution can switch between the two threads at any time.
- For the sake of simplicity, we assume that each operation is executed in an atomic manner, i.e., there is no switch (called context switch) during the execution of ax and by.
- Which values of u are possible at the completion of both tasks?

The figure at the end of this sheet shows a partial view of possible execution sequences. Each sequence corresponds to a path through the graph from the top to the bottom. Complete these pages and add the values of u to the edges! Sequences which are infeasible due to the values of u can be either crossed out or left out right away.

Solution:

- Start $\rightarrow$ Thread a $\rightarrow \ldots \rightarrow 6,7,7,7,7,7,7,7,7,7,7$
- Start $\rightarrow$ Thread b $\rightarrow \ldots \rightarrow 10,8,8,8,8,8,8,8,8,8,4$

6 Semaphores

Suppose that the code of the previous question is modified such that if-statements are protected by semaphores:

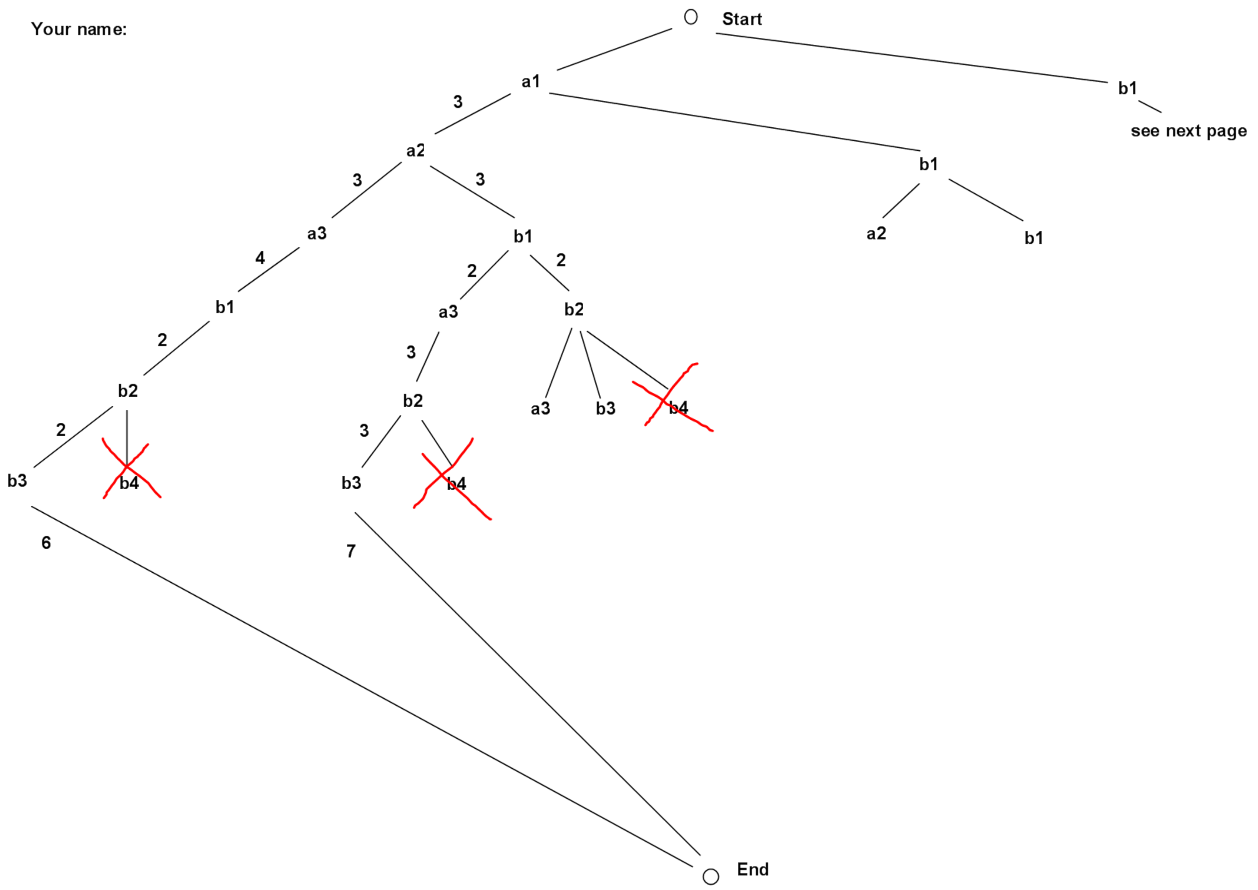
```
semaphore S;
integer u;
```

```
thread a {
u = 3;              //op a1
P(S);
if u<10             //op a2
   {u = u + 1; ..} //op a3
else u=5;           //op a4
V(S);
};
```

```
thread b {
u = 2;              //op b1
P(S);
if u<4              //op b2
  {u = u + 4; ..}   //op b3
else u=10;          //op b4
V(S);
};
```

Subject to the constraint imposed by the semaphore operations, threads can be executed in any sequence and the execution can switch between the two threads at any time. Generate a graph reflecting possible execution sequences of operations, similar to the one generated in the previous assignment. Add possible values of u to the edges. Sequences which are infeasible due to the values of u can be either crossed out or left out right away.

Your name:



Solution:

- Start $\to$ Thread a $\to \ldots \to 6, 7, 7, 7$
- Start $\to$ Thread b $\to \ldots \to 4, 8, 10, 8$

Your name