Real-Time Interfaces

Lothar Thiele

Ernesto Wandeler, Nikolay Stoimenov

ETH Zurich, Switzerland

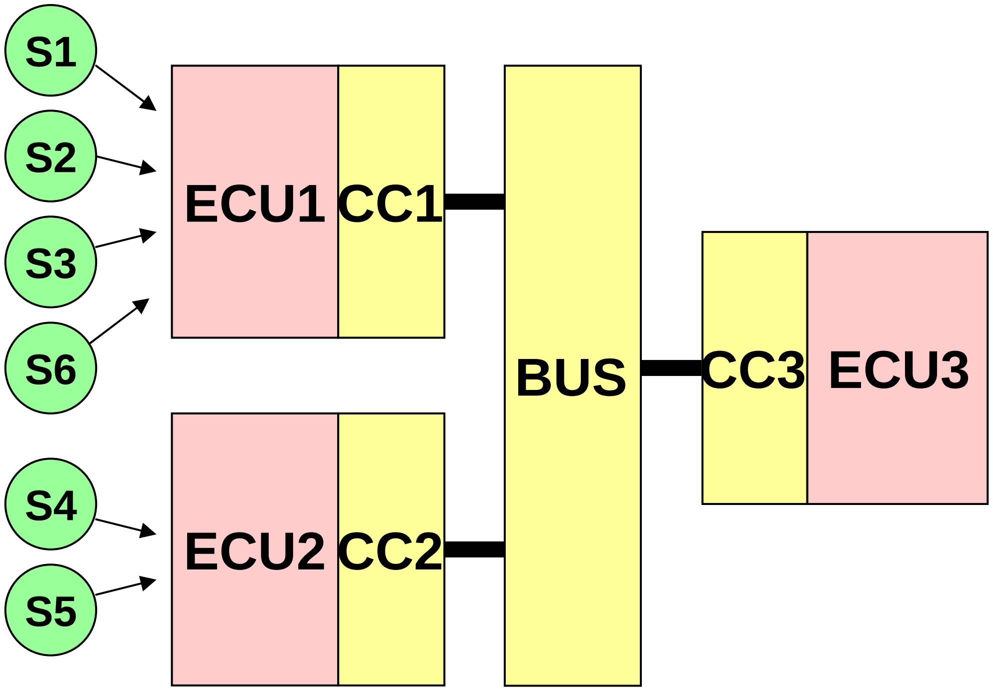
Embedded Systems

Embedded System =

Computation/Communication +
Resource Interaction

Resources should be first class citizens of analysis and design methods

Case Study



6 Real-Time Input Streams

- with jitter
- with bursts
- deadline > period

3 ECU’s with own CC’s

13 Tasks & 7 Messages

- with different WCED

2 Scheduling Policies

- Earliest Deadline First (ECU’s)
- Fixed Priority (ECU’s & CC’s)

Hierarchical Scheduling

- Static & Dynamic Polling Servers

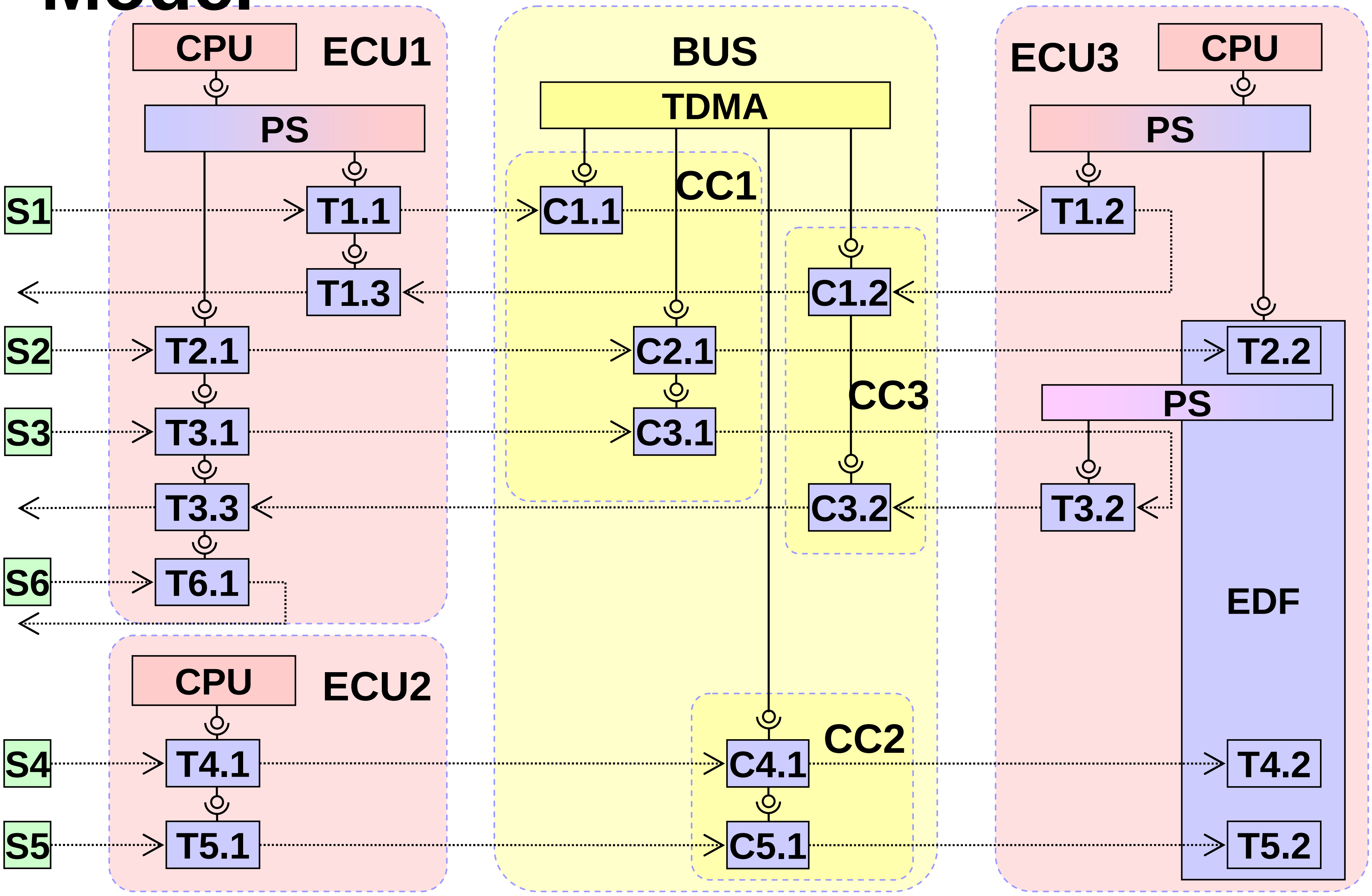
Bus with TDMA

- 4 time slots with different lengths
  (#1,#3 for CC1, #2 for CC3, #4 for CC

Total Utilization:

- ECU1	59 %
- ECU2	87 %
- ECU3	67 %
- BUS	56 %

... and its Abstract Component Model



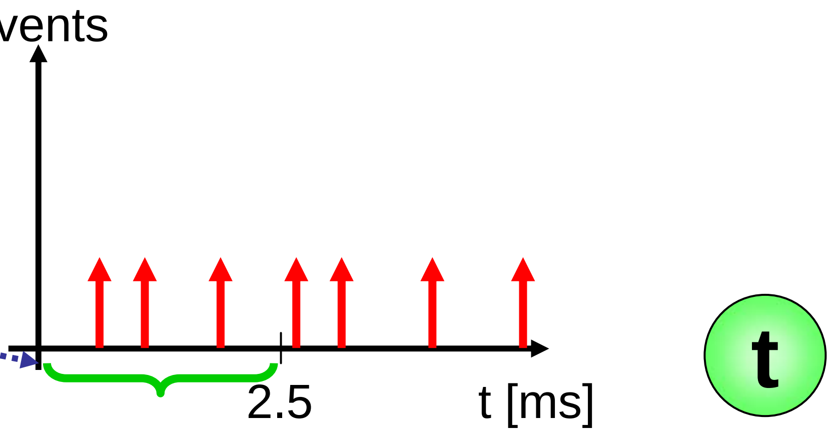
What types of component interactions are directly supported ?

- Processes communicate via event streams
  - may have identity
  - asynchronous interaction
- A few firing rules are supported (currently)
  - OR activation (process is activated for each event)
  - AND activation (process needs token on each input)
  - variable consumption and production rates of tokens
- ***Coarse model with rich analysis structure***

Abstract Stream Model

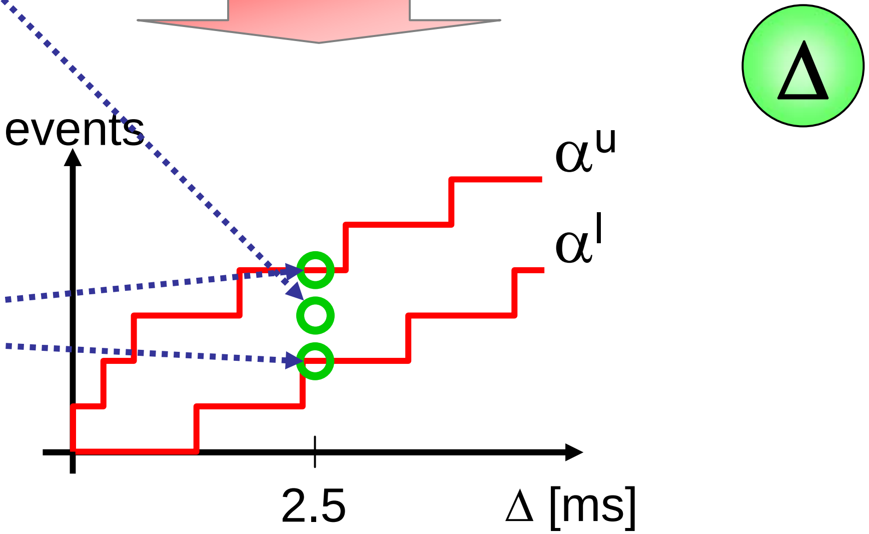
Event Stream

number of events in
in t=[0 .. 2.5] ms

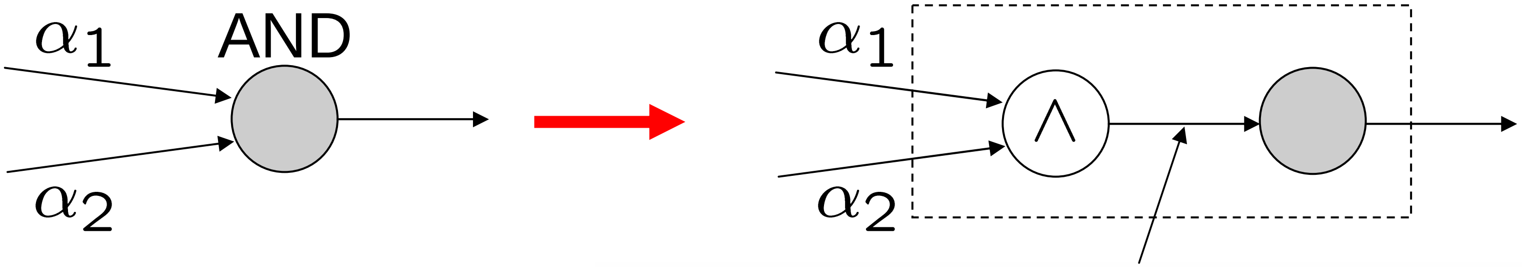


Arrival Curves

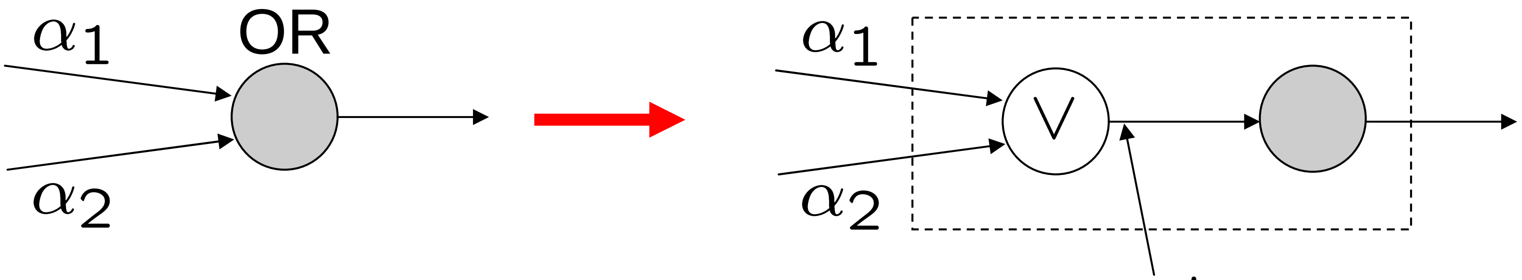
maximum / minimum arriving events in *any interval* of length 2.5 ms



Basic Concepts for Describing Components?



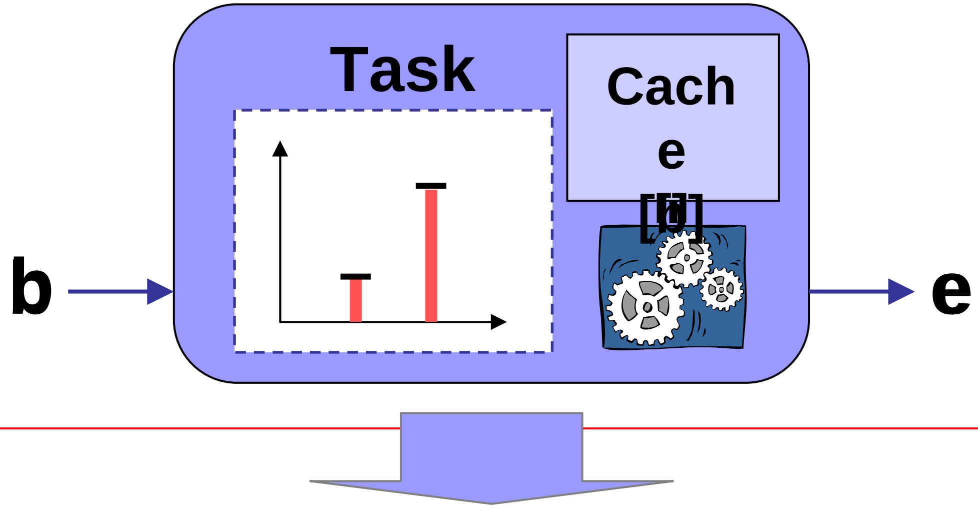
$$\max\left\{\min\left\{\alpha_1^u \oslash \alpha_2^l + B_1^0 - B_2^0, \alpha_2^u\right\},\right.$$
$$\left.\min\left\{\alpha_2^u \oslash \alpha_1^l + B_2^0 - B_1^0, \alpha_1^u\right\}\right\}$$



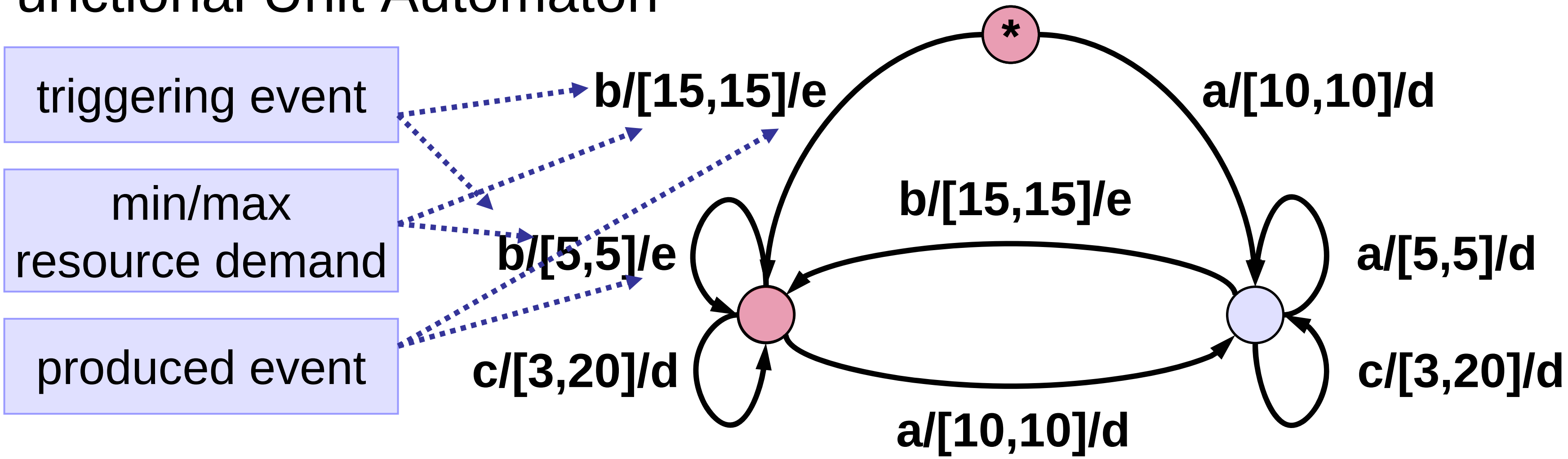
$\alpha_1 + \alpha_2$

Process Abstraction

Formal Specification
Program Analysis
Data Sheets
...



Functional Unit Automaton

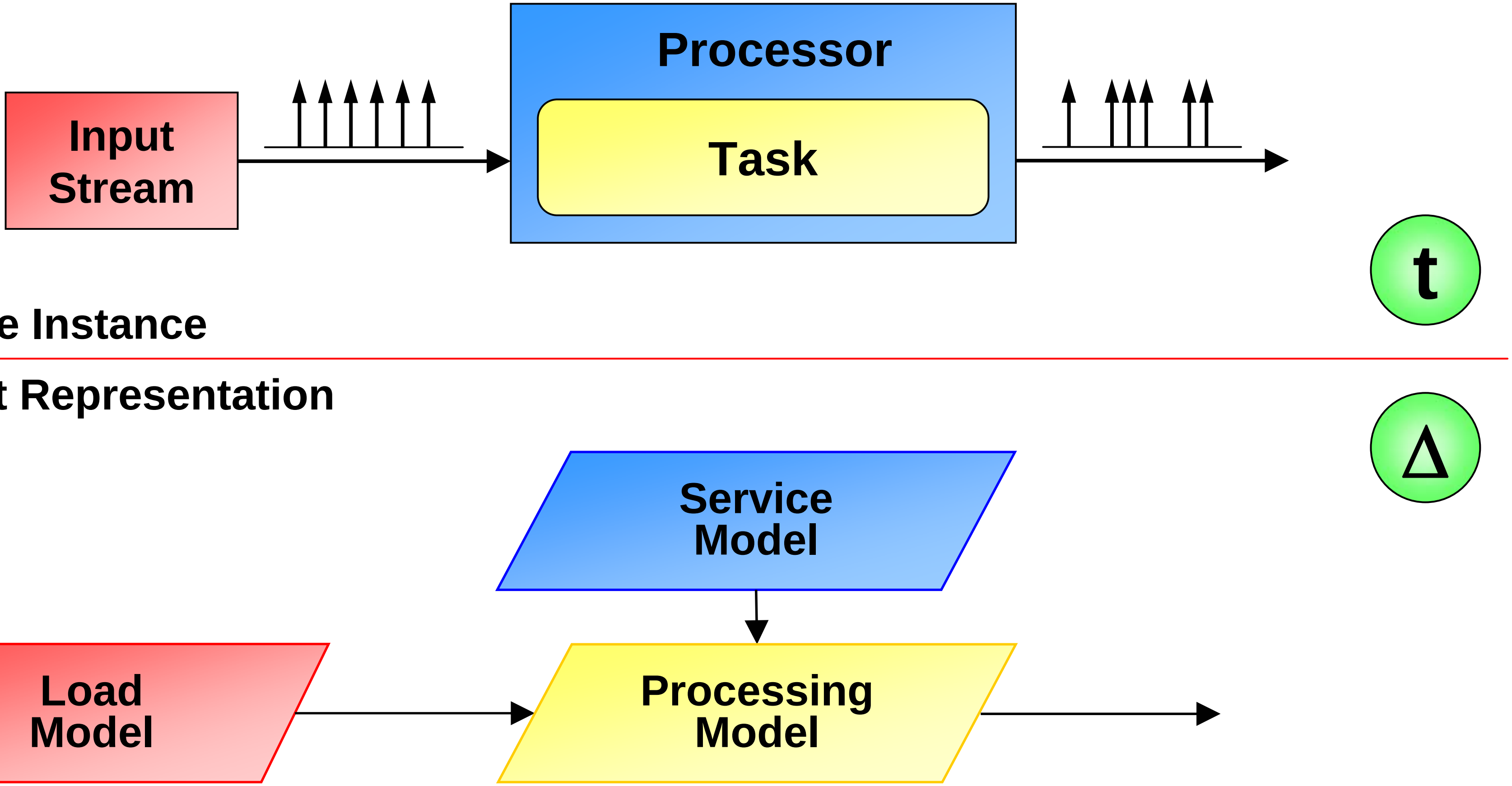


triggering event

min/max resource demand

produced event

What kind of resources can be modeled?



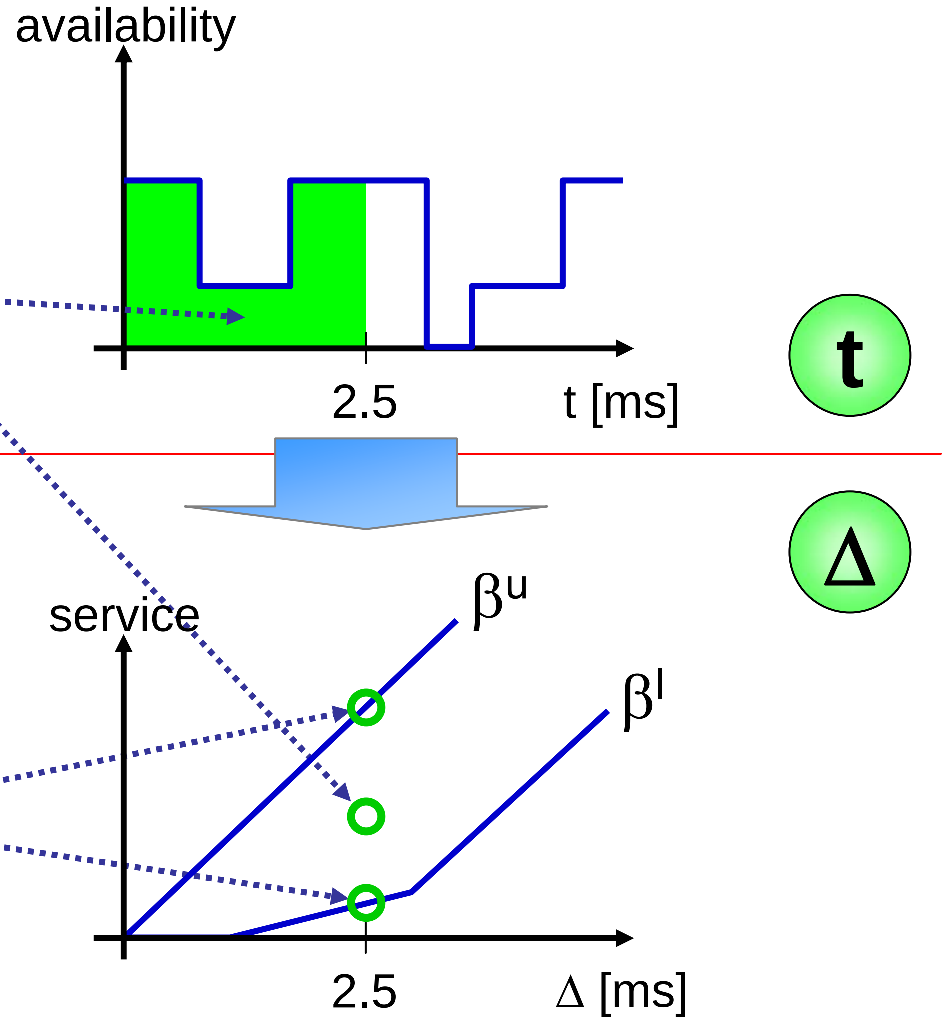
Service Model (Resources)

Resource Availability

available service
in t=[0 .. 2.5] ms

Service Curves

maximum/minimum
available service in *any interval* of length 2.5 ms



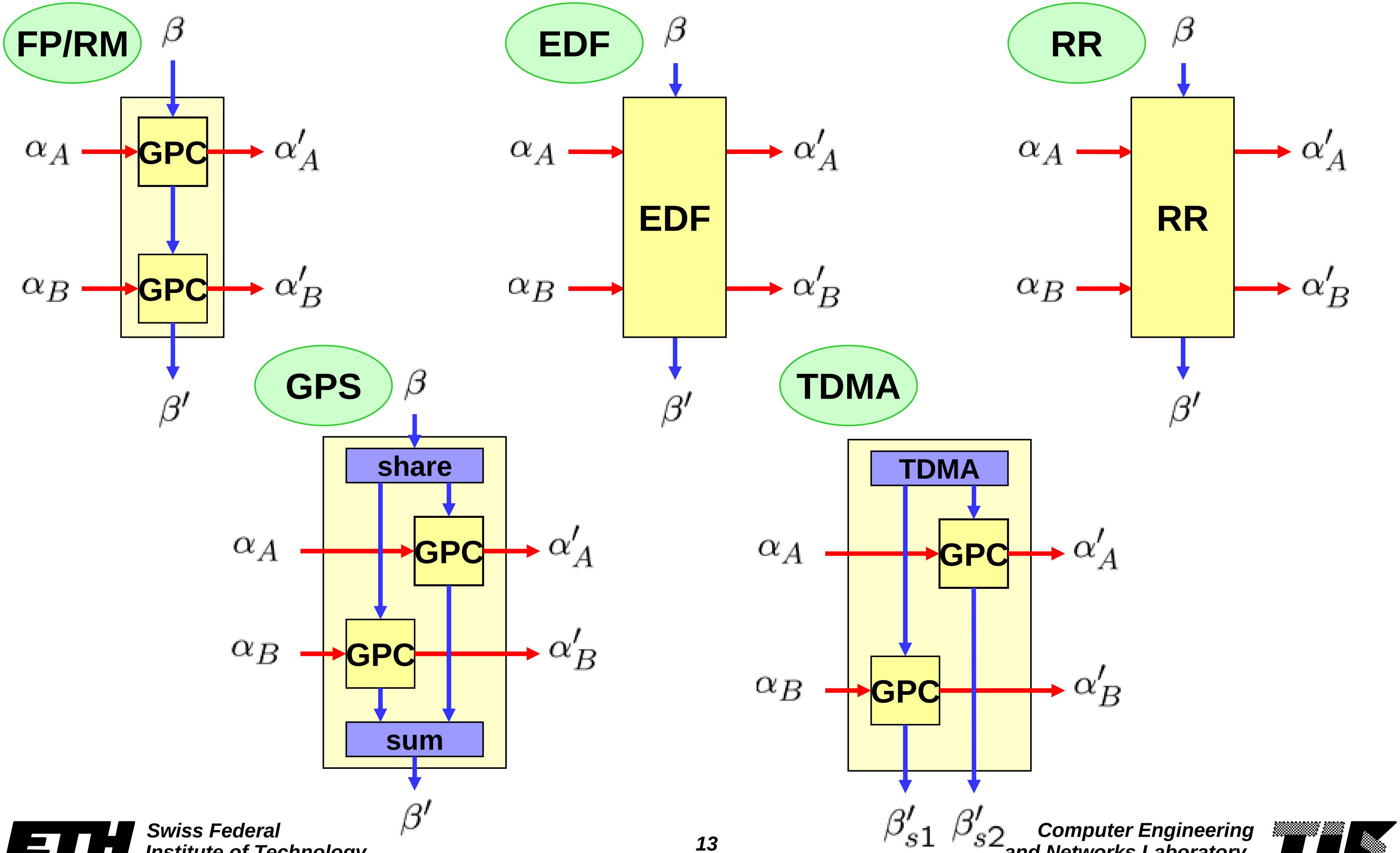
What kind of resources can be modeled?

- Memory (buffer space)
- Delay (end-to-end delay / processing and waiting)
- Computation
- Communication
- Energy

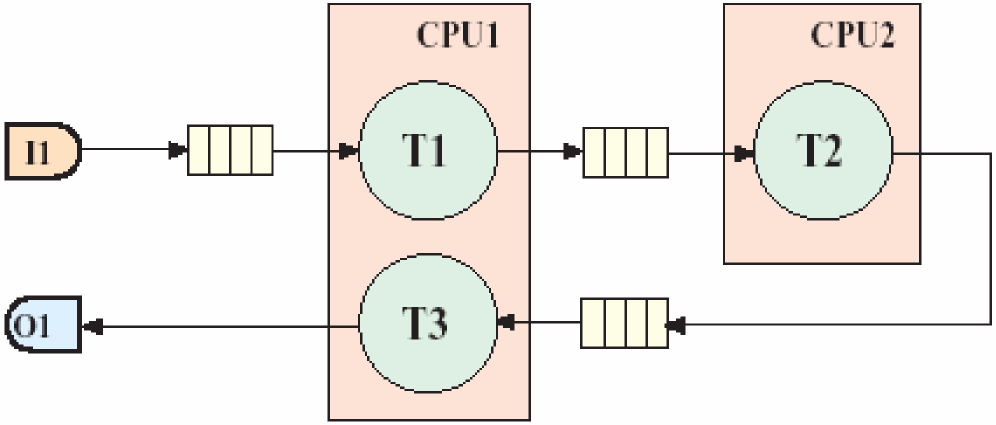
What kind of resource usage can be modeled?

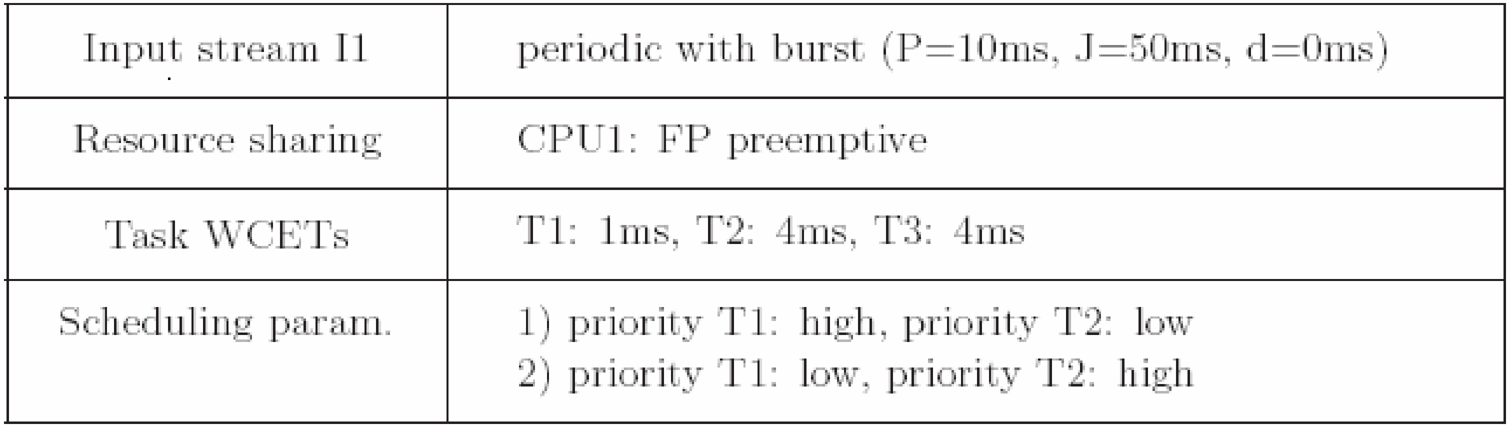
- Different resource sharing strategies
  - EDF
  - TDMA
  - Fixed Priority
  - GPS
- Different processing semantics
  - Greedy Processing
  - Greedy Shaper
  - Blocking

Scheduling and Arbitration



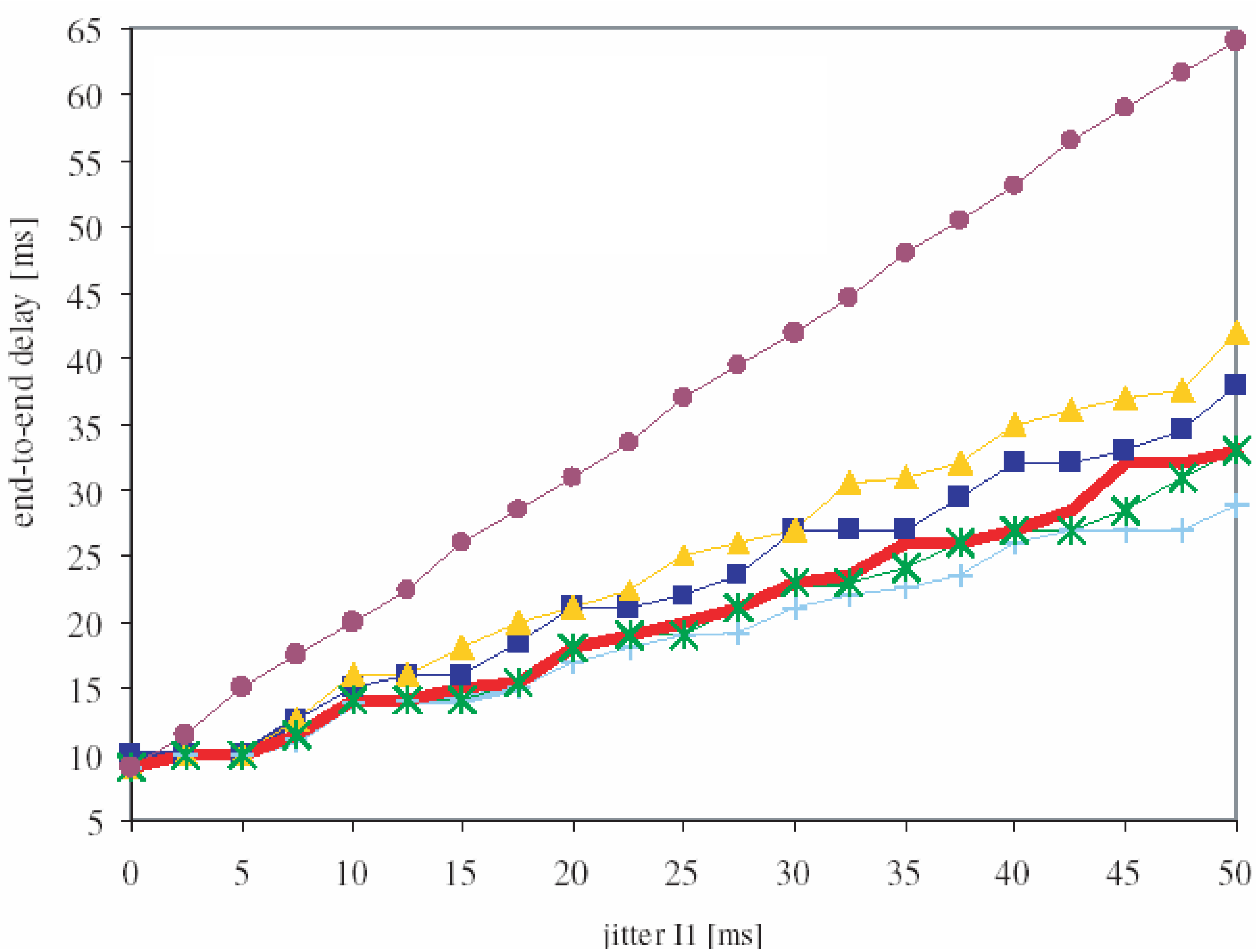
Does Abstraction Matter?



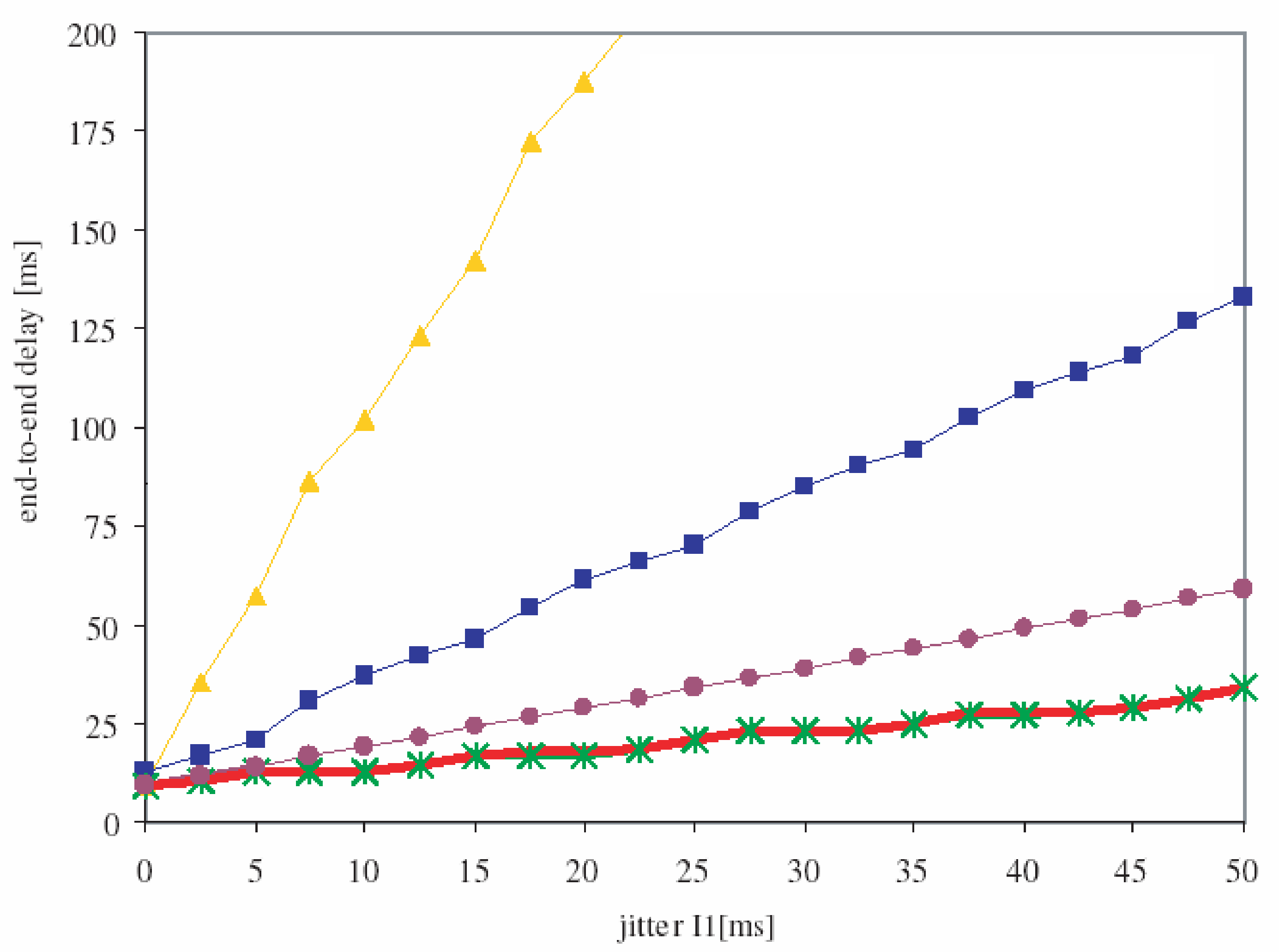


Input stream I1	periodic with burst (P=10ms, J=50ms, d=0ms)
Resource sharing	CPU1: FP preemptive
Task WCETs	T1: 1ms, T2: 4ms, T3: 4ms
Scheduling param.	1) priority T1: high, priority T2: low 2) priority T1: low, priority T2: high

Does Abstraction Matter?



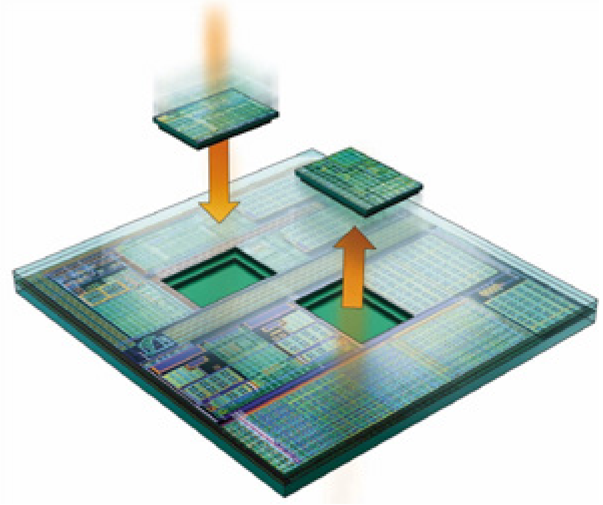
Does Abstraction Matter?



What kind of design methods should be supported ?

Embedded System =

Computation + Resource Interaction



Analysis:

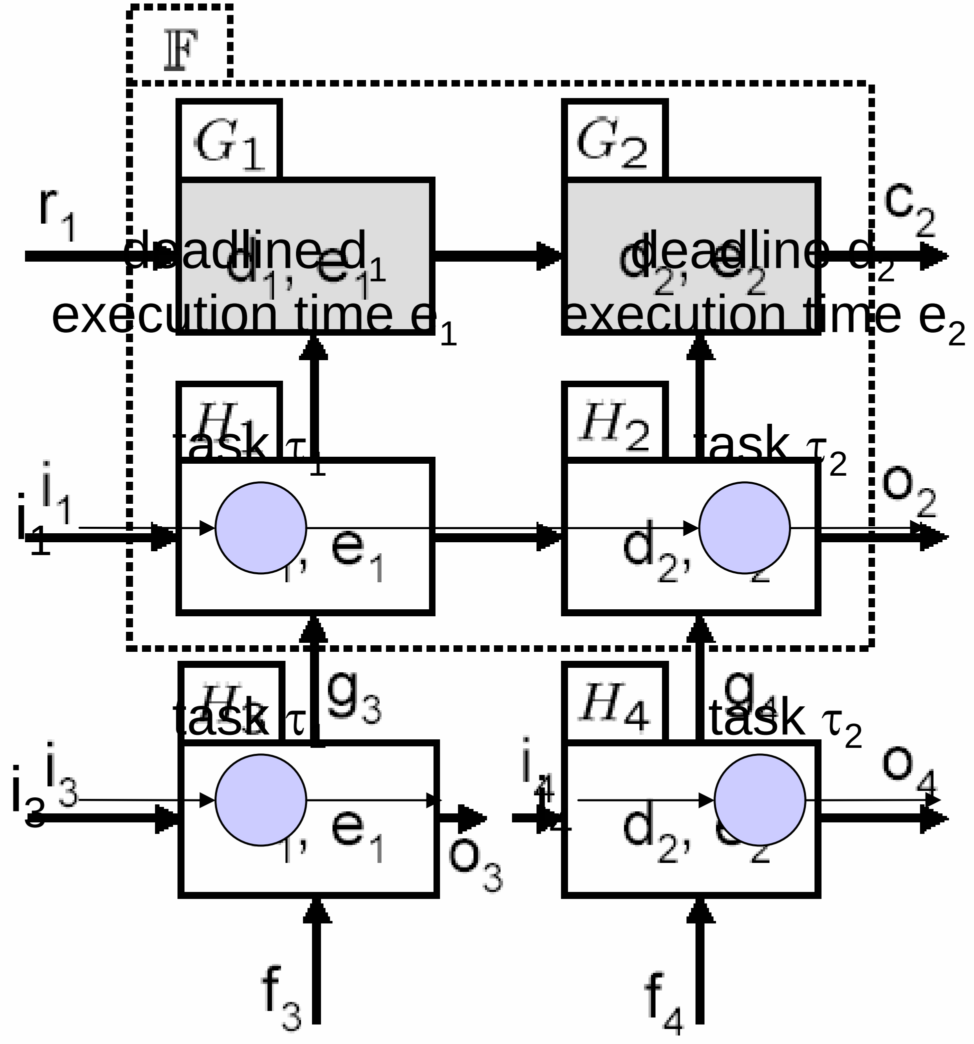
Infer system properties from subsystem properties.

Design:

Build a system from subsyste

while meeting requirements.

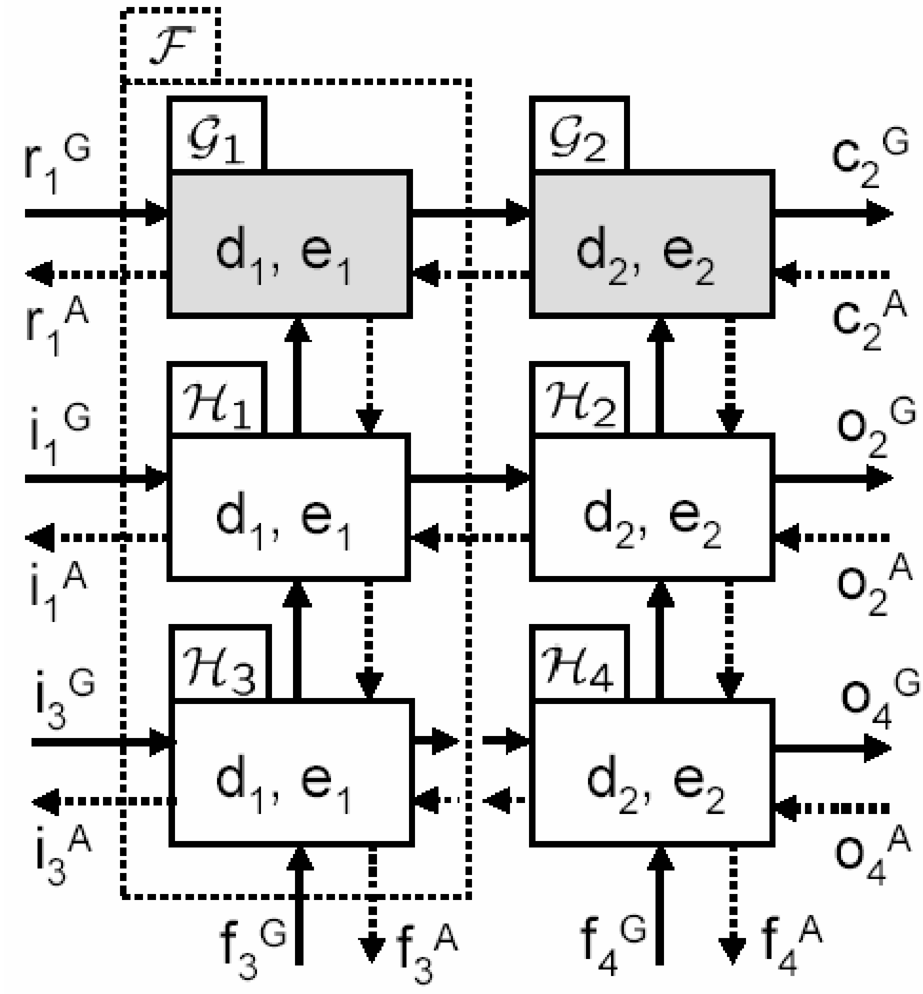
EDF – abstract components



EDF scheduling

task composition

EDF – interfaces



adaptive interfaces

scheduling

task composition

Questions

- ***Tradeoff between predictability and efficiency***
  - none (only hard bounds so far)
- ***Tools***
  - www.mpa.ethz.ch (Matlab toolbox)
- ***Industrial Case Studies***
  - IBM
  - Siemens VDO
  - Netmodule