

# COPROCESSOR SYNTHESIS OF MULTIRATE SYSTEMS USING STATIC SCHEDULING THEORY

**Romain KAMDEM**

Laboratoire d'Informatique de Marseille

CMI/Université de Provence

39, rue Joliot-Curie

13453 Marseille - France

*R.Kamdem@ibsm.cnrs-mrs.fr*

**Alain FONKOUA**

Synopsis-Leda

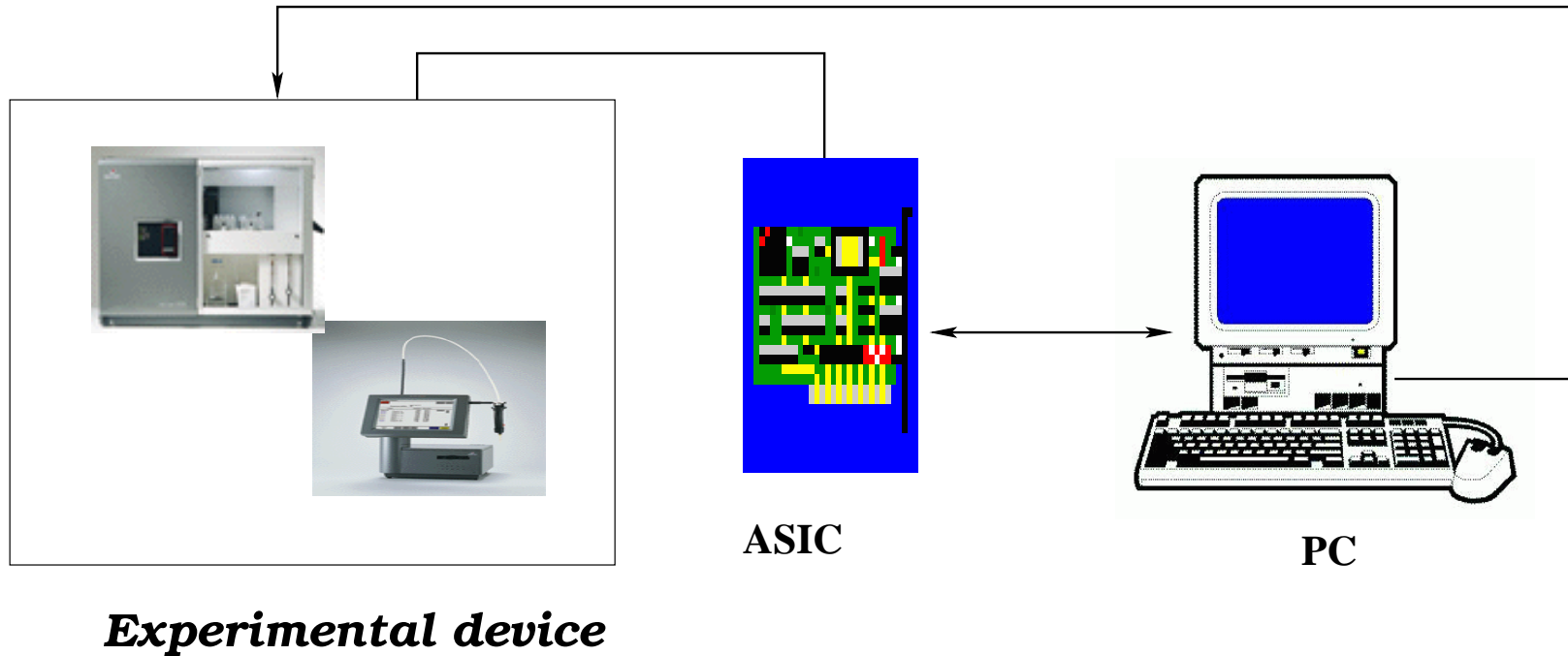
5, rue du Tour de l'eau

38400 Saint-Martin d'Herès, France

*fonkoua@synopsis.fr*

# MOTIVATIONS

## *Actions*



- 100% hardware  $\implies$  cost problem
- 100% software  $\implies$  performance problem

**Hardware/software  $\implies$  compromise cost/performance**

# LAYOUT

- ❑ Motivations
- ❑ Partitioning problem
- ❑ Coprocessor partitioning algorithm
- ❑ Experimental results
  - ▣▶ Biology application
  - ▣▶ Telecommunication application ( $\text{GMDF}_\alpha$ )
- ❑ Conclusion

# PARTITIONING PROBLEM

## A - Specification

**Experiments involve sensors and captors  
controlled by drivers**

The system is specified by:

- $F = \{t_i\}_{1 \leq i \leq n}$  a set of tasks
- $G \subseteq F \times F$  direct acyclic graph that induces partial order over  $F$
- a set of deadlines  $D = \{D_i\}_{1 \leq i \leq n}$
- for each task  $t_i$  there is an associated data flow graph  $df g_i$
- Functionals units with their elementary cost

**We need to estimate the cost for the tasks**

# PARTITIONING PROBLEM

## B - Estimators

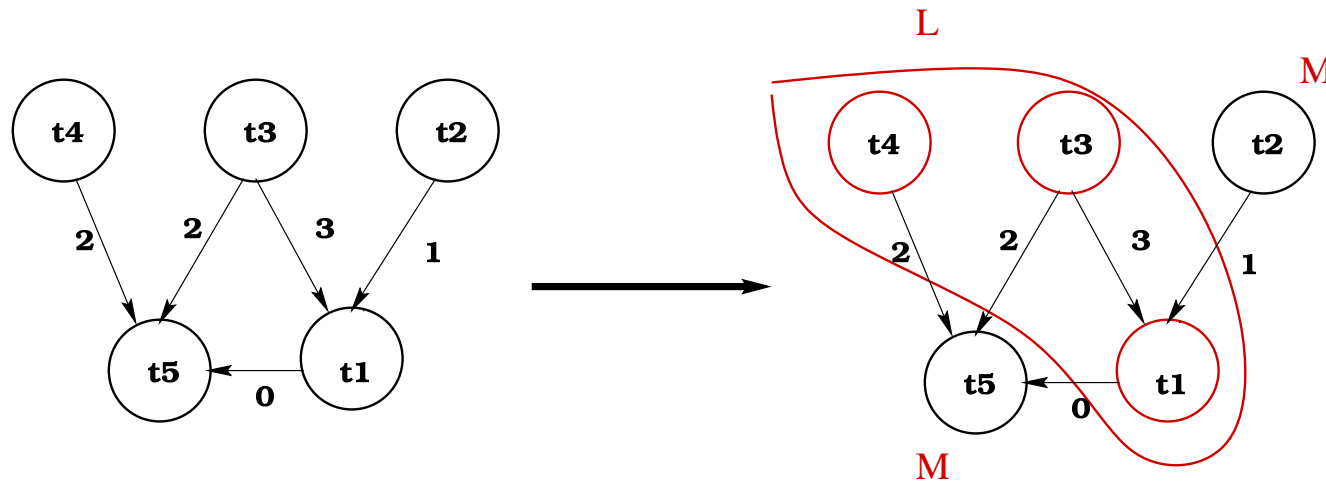
### Partitioning based on hw/sw estimation

- Software estimator :
  - *runtime\_eval(task,processor)*
- Hardware estimators :
  - *hardware\_eval(task,max\_time)*
  - *min\_time\_eval(task,hardware\_set)*

### Estimation based on dataflow/control flow graph

# PARTITIONING PROBLEM

## C - Problem definition



Propose a partition  $(H, S)$  such that:

- $H \cup S = F, H \cap S = \emptyset$  ( $H$  hardware,  $S$  software)
- all the tasks satisfy their constraints
- the overall hardware cost is reduced

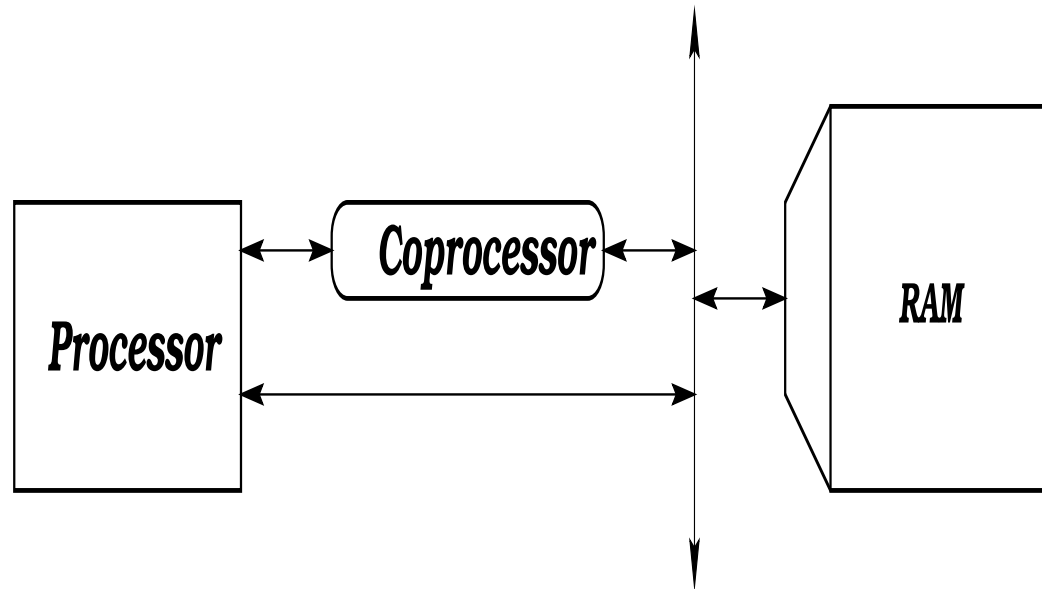
# COPROCESSOR APPROACH

## Principles of solution

- Static scheduling mechanism for assign priorities
- Prediction of worst-case response time  $R_i$  for each task  $t_i$
- Tasks are scheduled according to a static deadline monotonic priority
- Feasible partitions identification ( $\forall i, R_i \leq D_i$ )
- Criteria qualities for feasible solutions :
  - Minimal set of functionnals units
  - Margin(H,S) =  $\sum_i (D_i - R_i)$

# COPROCESSOR APPROACH

## A - Target architecture



This architecture allows the use of the static scheduling theory

# COPROCESSOR APPROACH

## B - Feasibility analysis

All the tasks can be considered as executing on the same processor

$$\Rightarrow R_i^{n+1} = C'_i + B_i + \sum_{\forall j \in hp(i)} \lceil \frac{R_i^n}{T_j} \rceil C_j \quad (\text{Audsley et al 1995})$$

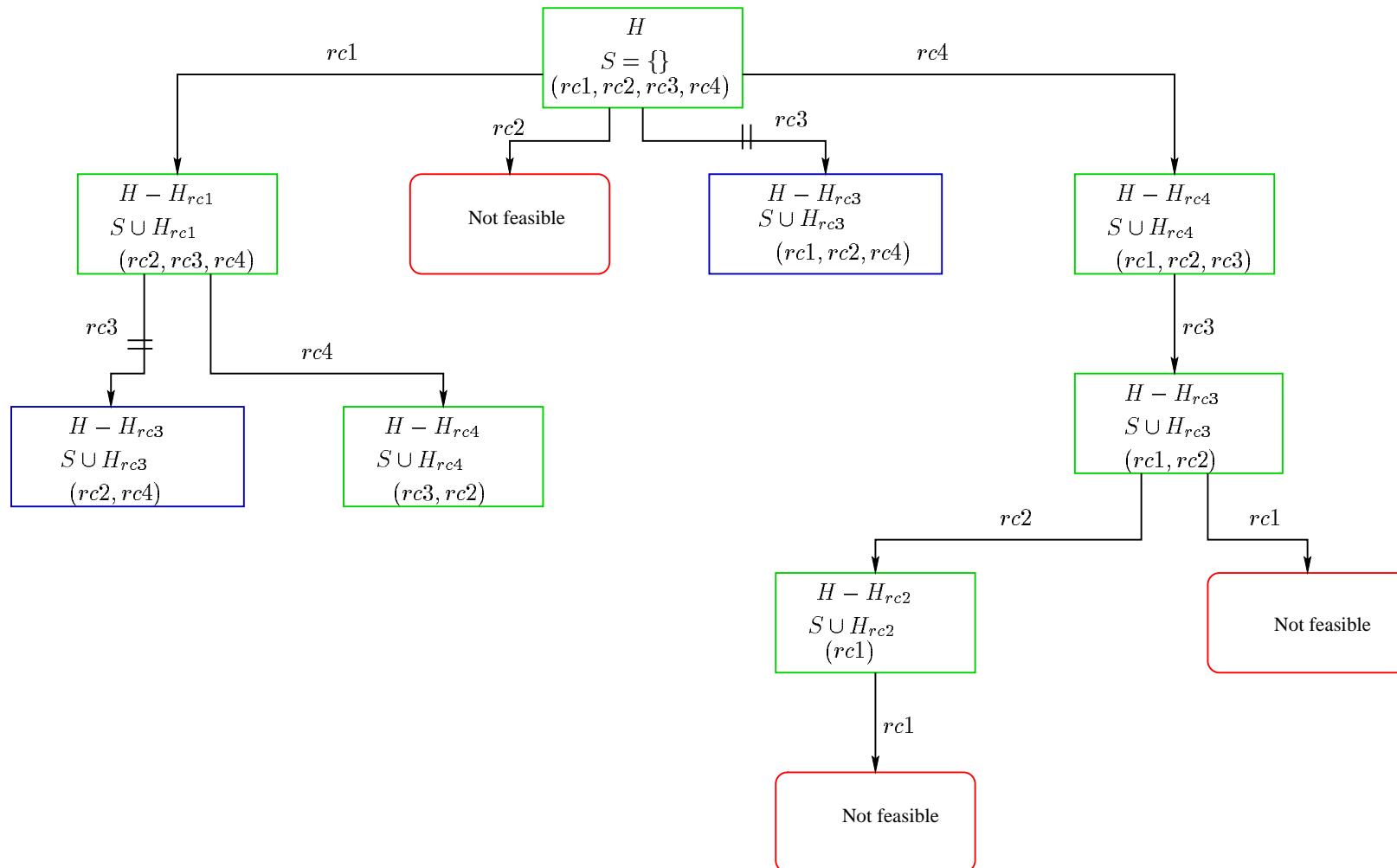
$$C'_i = \begin{cases} \text{Hw execution time if } t_i \in H \\ \text{Sw execution time if } t_i \in S \end{cases}$$

$$B_i = \max_{k \in lp(i)} (C_k'' + s_k \times v_k)$$

**A partition (H,S) is feasible if  $\forall t_i \in H \cup S, R_i \leq D_i$**

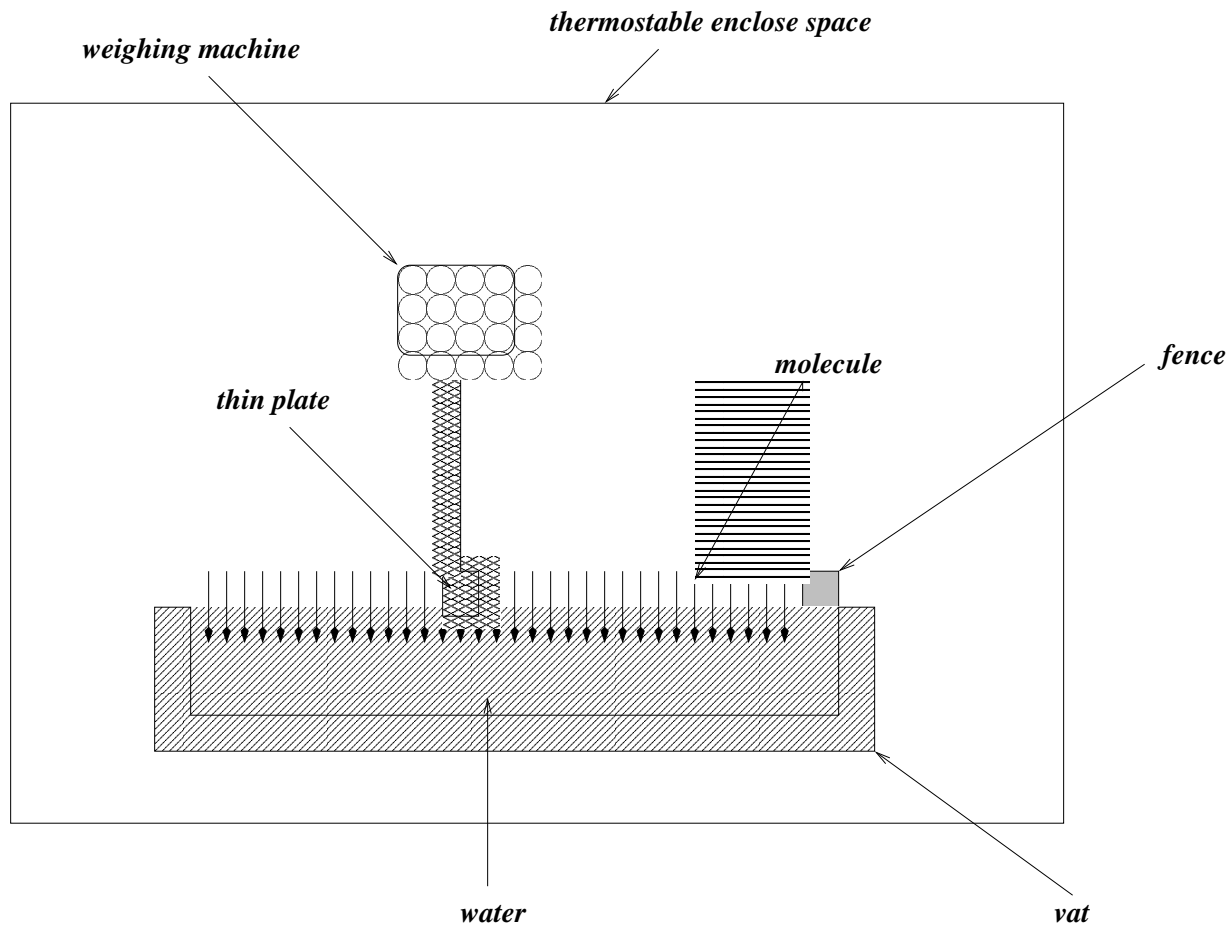
# COPROCESSOR APPROACH

## C - Partitioning algorithm



# EXPERIMENTAL RESULTS

## A - An experiment of enzyme kinetic of lipolysis



## EXPERIMENTAL RESULTS

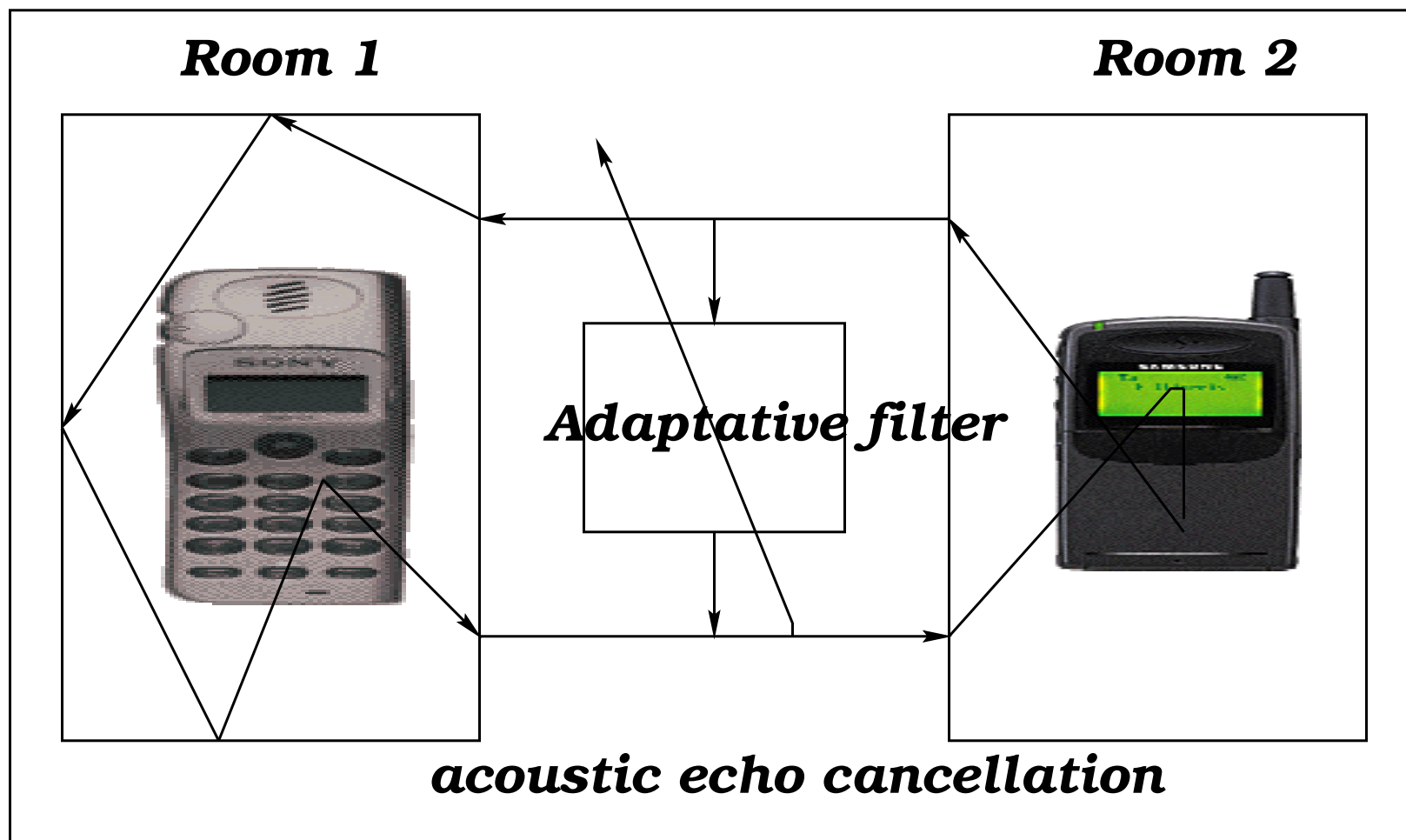
We apply our partitioning method on a real example

Tasks	$C_i$	$T_i$	$B_i$	$D_i$
$t_1$	17	100	4	81
$t_2$	20	100	3	72
$t_3$	44	150	5	100
$t_4$	8	42	3	32
$t_5$	30	84	6	57
$t_6$	39	104	5	70
$t_7$	8	1000	9	24
$t_8$	35	208	6	136
$t_9$	28	400	9	300

$F \setminus F$	$t_1$	$t_2$	$t_3$	$t_4$	$t_5$	$t_6$	$t_7$	$t_8$	$t_9$
$t_1$	0	0	0	0	0	1	1	0	0
$t_2$	0	0	0	0	0	0	1	0	1
$t_3$	0	0	0	1	0	0	1	1	1
$t_4$	0	0	1	0	1	1	0	0	0
$t_5$	0	0	0	1	0	0	0	0	1
$t_6$	1	0	0	1	0	0	0	1	0
$t_7$	1	1	1	0	0	0	0	0	1
$t_8$	0	0	1	0	0	1	0	0	0
$t_9$	0	1	1	0	1	0	1	0	0

$$S = \{t_1, t_2, t_7, t_8, t_9\}, H = \{t_3, t_5, t_6, t_4\}, \delta = 145, \text{cost} = 18091$$

# EXPERIMENTAL RESULTS (GMDF $\alpha$ )



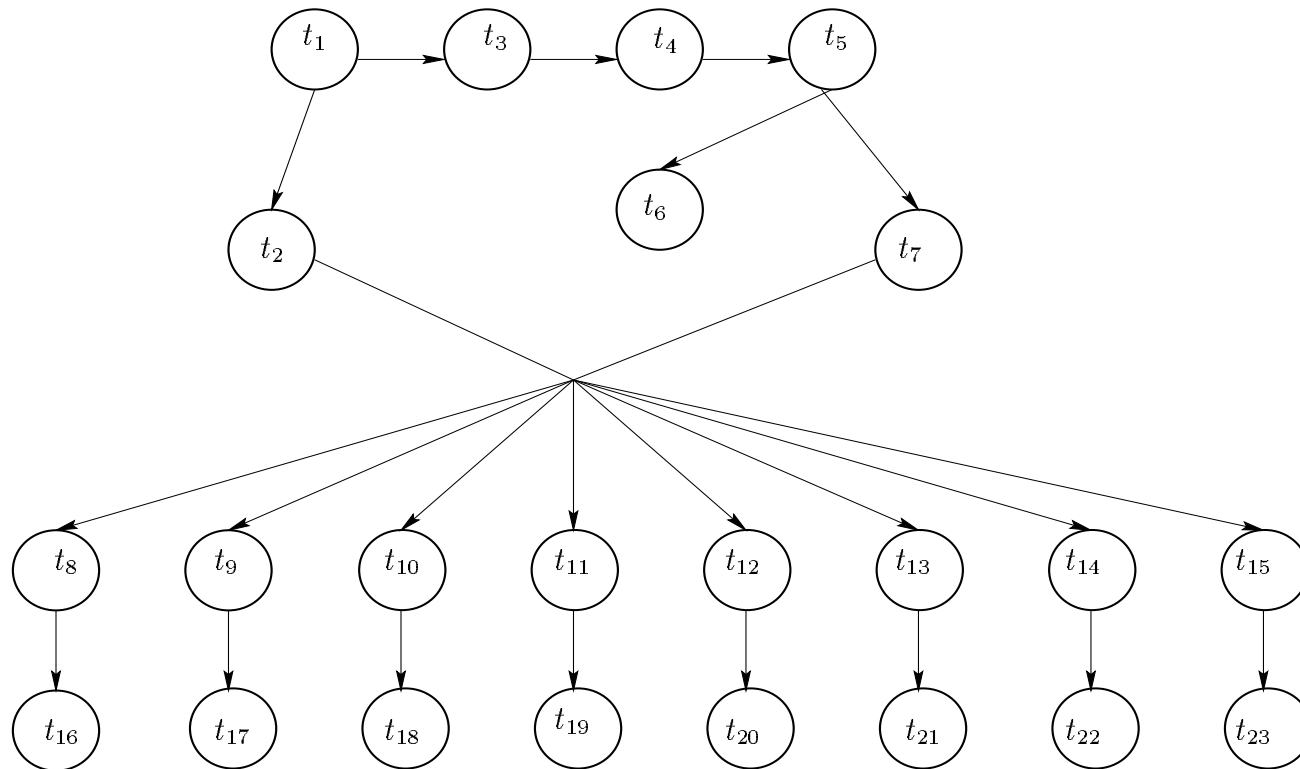
Tasks	$DSP\_C_i$	$T_i$	$D_i$	hw_op
fft_in ( $t_1$ )	450	8000	7501	fft
norm ( $t_2$ )	472	8000	7411	-
out_t ( $t_3$ )	730	8000	7588	conv
inv_fft ( $t_4$ )	470	8000	7701	ifft
err_t ( $t_5$ )	62	8000	7788	conv
wola ( $t_6$ )	34	8000	8000	conv
fft_err ( $t_7$ )	406	8000	7796	fft
F1 ( $t_8$ ) to F8 ( $t_{15}$ )	548	8000	7883	ifft
G1 ( $t_{16}$ ) to G8 ( $t_{23}$ )	451	8000	8000	fft

Functionnal units	Cost ( $mm^2$ )
fft	1.80
ifft	1.80
conv	0.57

## GMDF $\alpha$ (Freund et al 1997)

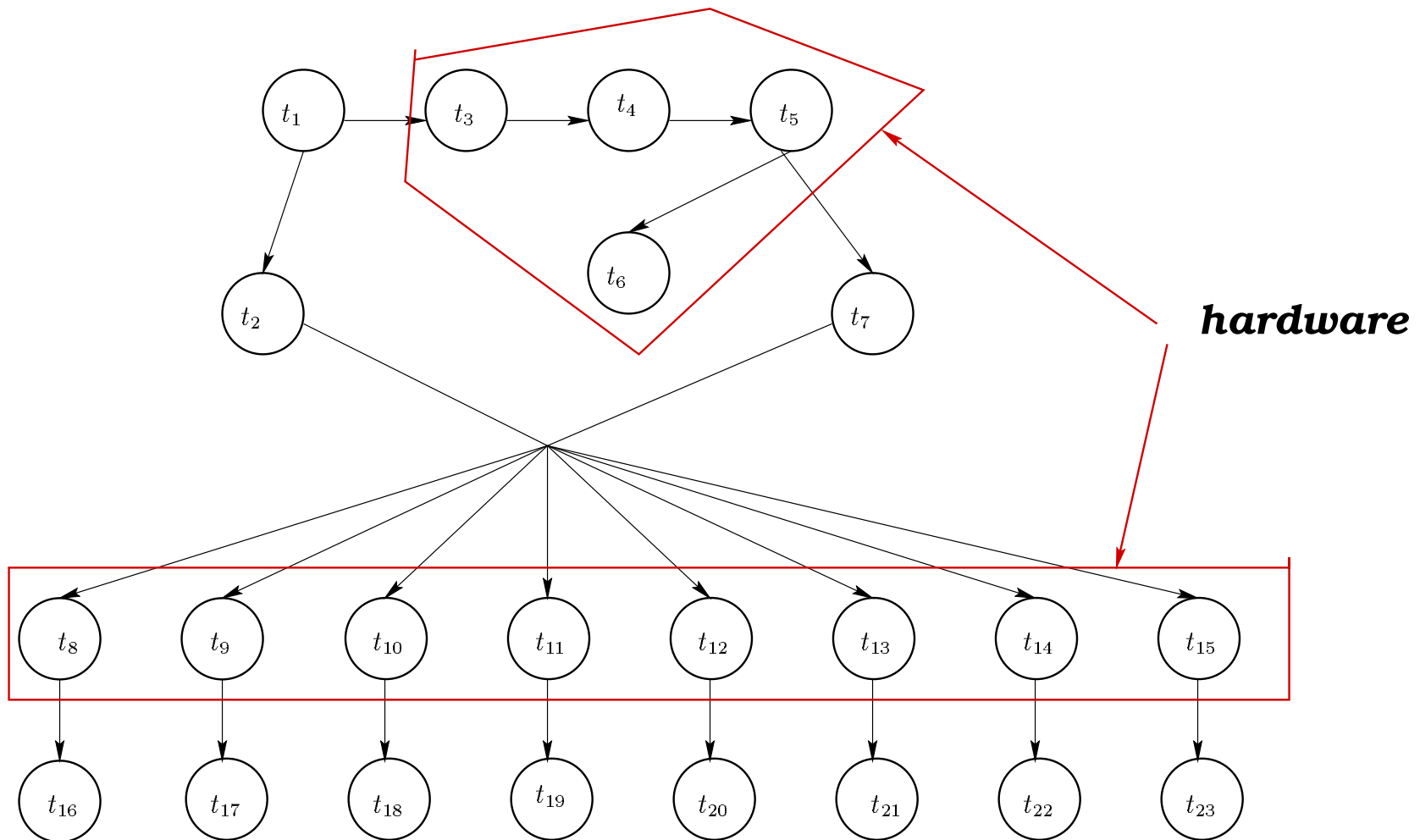
# EXPERIMENTAL RESULTS (GMDF $\alpha$ )

## Precedence graph



# EXPERIMENTAL RESULTS (GMDF $\alpha$ )

Coprocessor Approach (hardware cost =  $2.37mm^2$ )



## CONCLUSION

### **new efficient partitioning algorithm**

- Find feasible solution with smallest hardware cost
- Combines branch and bound and scheduling analysis
- Search space reduced compare to D'Ambosio and Hu similar method (1994)
- Proposes a good compromise between flexibility and hardware cost
- Not allows parallelism

### **Further work**

- Extend to other target architecture
- Extend to distributed hard real-time systems whose components are connected via an Ethernet network