Moving Average Frequency Reduction for Low Power in Hard Real Time Systems

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Low Power in Real Time OS

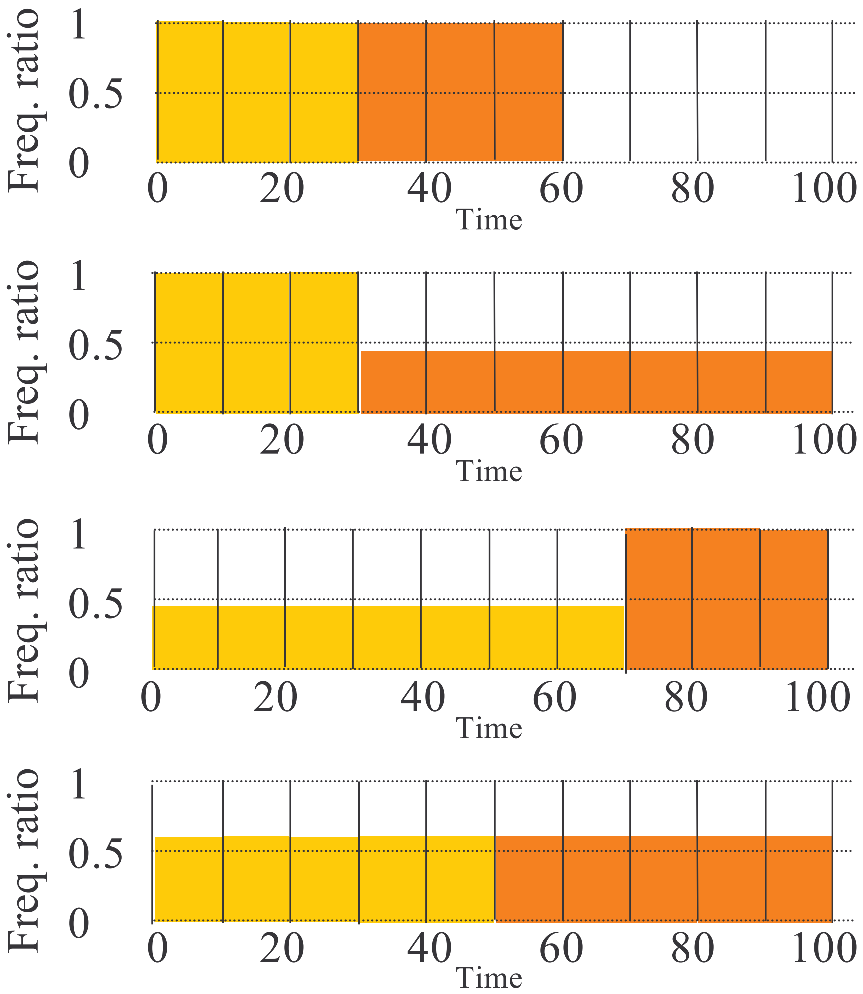
- Mandatory:
  - Guaranteeing all deadlines $\sum \frac{C_i}{T_i} \leq 1$
  - Hardware allows DVS
- How to do it?

Scheduling → Trade off → Low power

Scheduling → Dual Priority (DP)

Low power → DVS

Different Policies



E=60

E=35.2

E=35.2

E=21.6

$$E = \sum v^3 * t$$

When the processor can reduce the speed?

- Periodic tasks in Dual Priority scheduling (DP):
  - 3 queues:
    - URQ with a RMA priority policy assignment
    - ARQ with a FIFO policy for aperiodic tasks
    - LRQ with any priority policy assignment (Least Promotion First)
    - Tasks promotes whenever they need to hurry
- Low Power algorithm:
  - No tasks in the URQ ⇒ minimum frequency
  - 1 task in the URQ ⇒ reduce the frequency meeting the deadlines
  - > 1 task in the URQ ⇒ maximum frequency

Average frequency reduction policy

First approach:

$$BU = \sum_{\forall \tau_i} \frac{\alpha C_i}{T_i}$$

Where α the minimum increment that will cause at least one task to miss its deadline

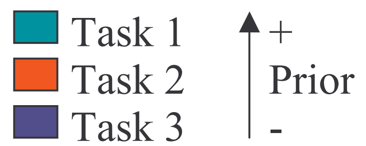
We propose:

Lower Bound for frequency reduction = $1/\alpha$

Enhanced Power Low Dual Priority Scheduling

- How it works:
  - Execute the highest priority task in the highest priority queue with a fixed priority assignment (original DP)
  - Execute periodic tasks at average frequency reduction provided the time constraints impose by the HRT systems
  - Adjust the clock speed along with voltage supply to reduce power consumption (DVS)

Clock frequency in EPLDP (1)

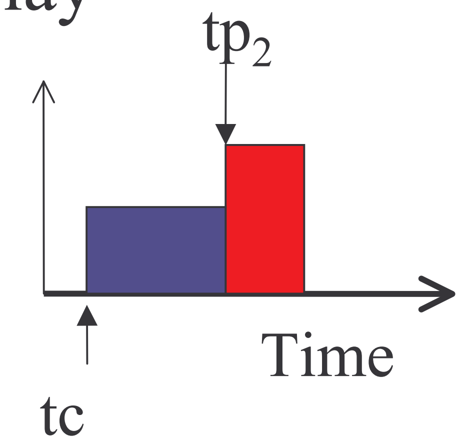


- Run queues empties

  Time power down = ta_k – wakeup delay

- There is only one task in the URQ

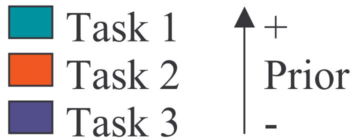
$$Freq\ ratio = \max\left(\frac{\min(tp_k - tc, remainig(C_i))}{\min(tp_k, td_i) - tc}, \frac{U_{rem}}{BU}\right)$$



- More than one task in the URQ

$Freq\ ratio = 1$ // Maximum clock speed

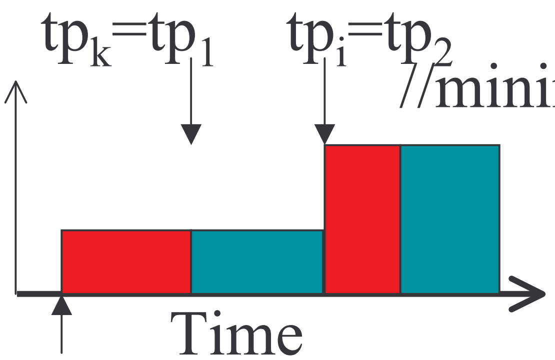
Clock frequency in EPLDP (2)



- there are an active LRQ task and URQ empty

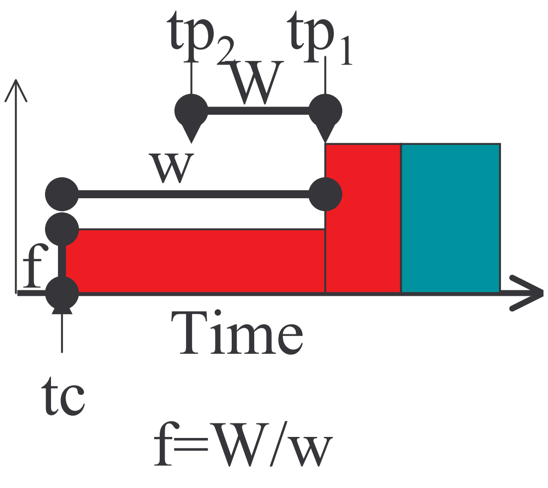
<u>if</u> $tp_k < tp_i$ <u>then</u> //minimum efficient speed

$$Freq\ ratio = \frac{U_{rem}}{BU}$$

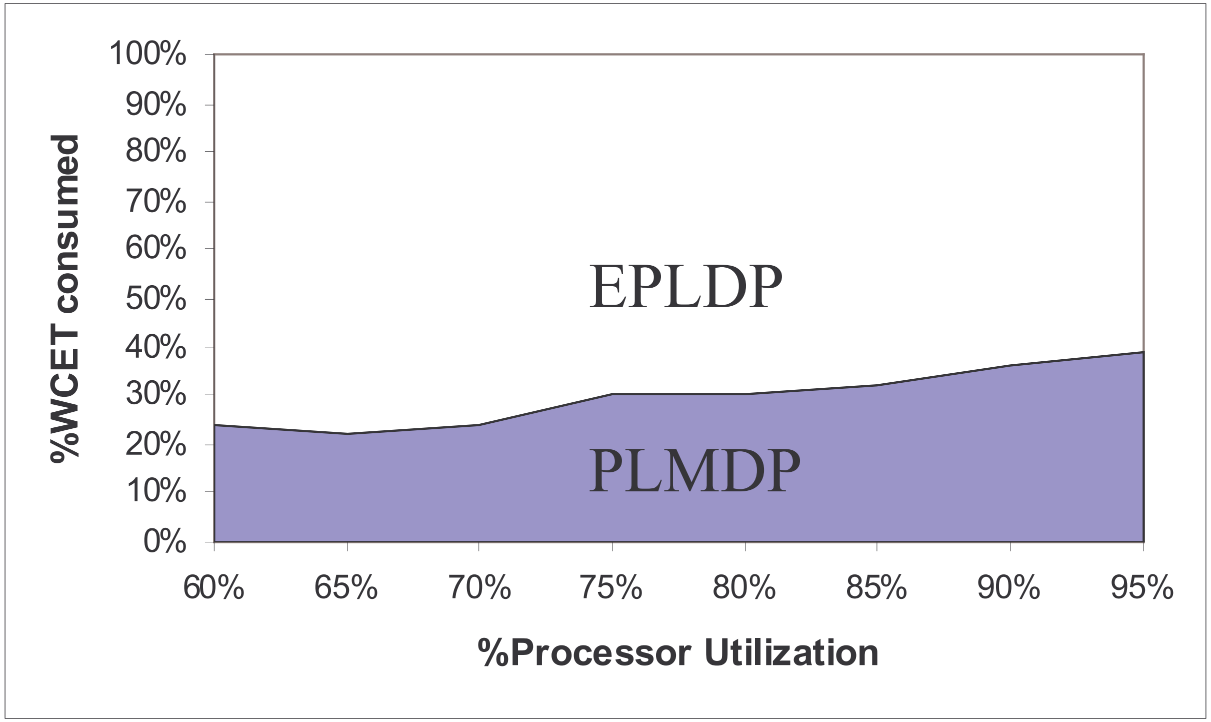


<u>else</u>

$$Freq\ ratio = \max\left(\frac{\min(tp_k - tp_i, remainig(C_i))}{\min(tp_k, td_i) - tc}, \frac{U_{rem}}{BU}\right)$$



Performance Transition EPLDP-PLMDP



100 task sets

8 harmonic tasks

Max workload=20%

T=D

WCET estimation: Moving Average

L1 $U_0 = \sum_{\forall \tau} C_i \qquad EU = U_0$

L2 i=1;

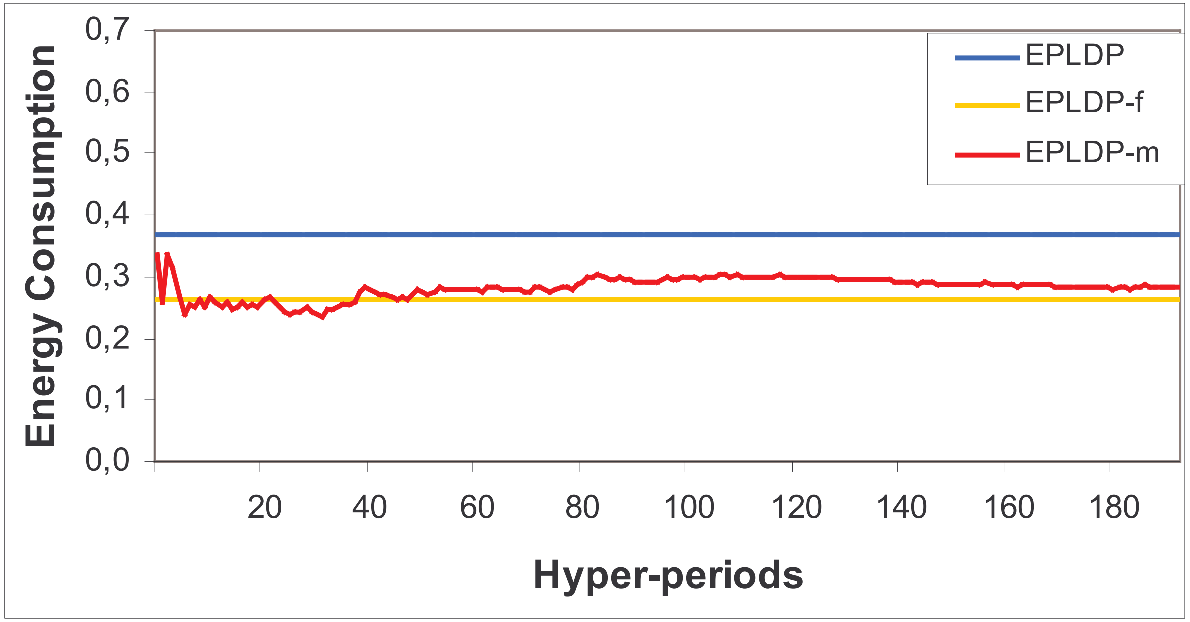
L3 while real_time_application_not_finished do

L3 execute hyper-period i with EU and update U_i;

L4 $\overline{U} = \frac{(\overline{U} * i) + U_i}{i+1} \qquad EU = U_i - \overline{U}$

L5 enddo

Moving average results



U=80%

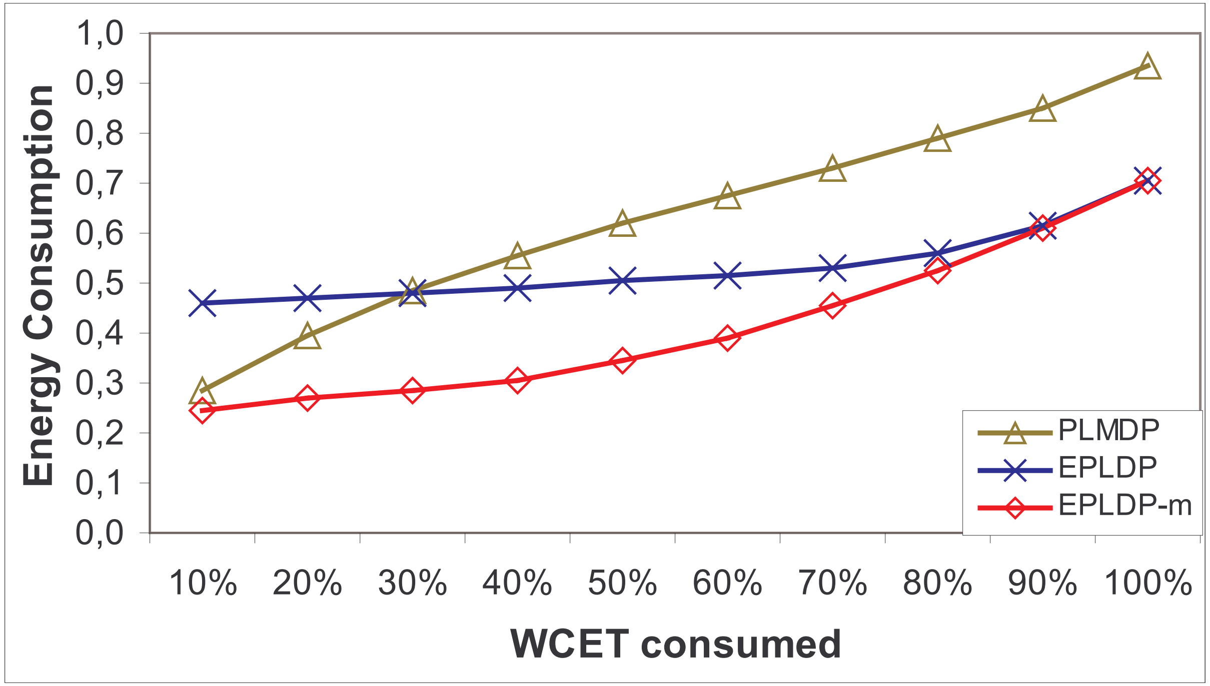
8 harmonic tasks

Max Workload=20%

C=gaussian distrib with average=50%

standard dev=10%

Comparative synthetic benchmark



U=80%

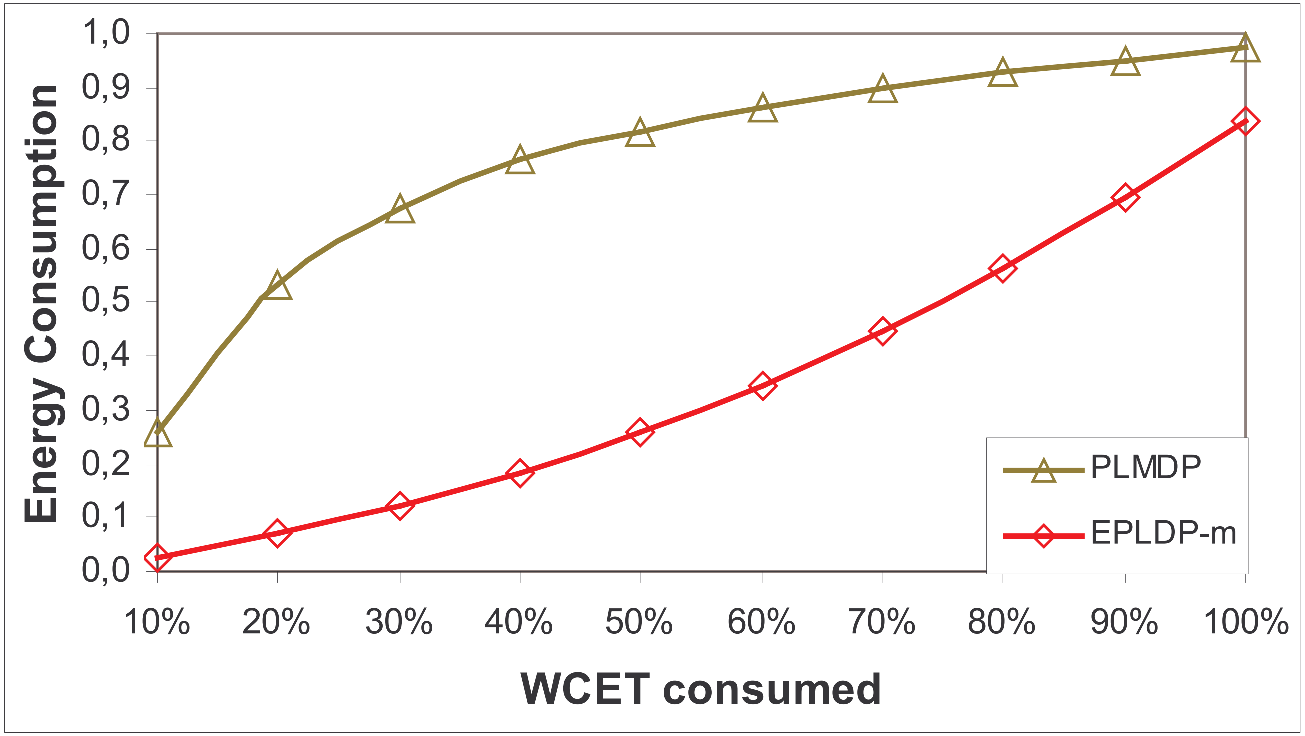
8 harmonic tasks

Max Workload=20%

C=gaussian distrib

standard dev=10%

Avionics task set benchmark



17 tasks

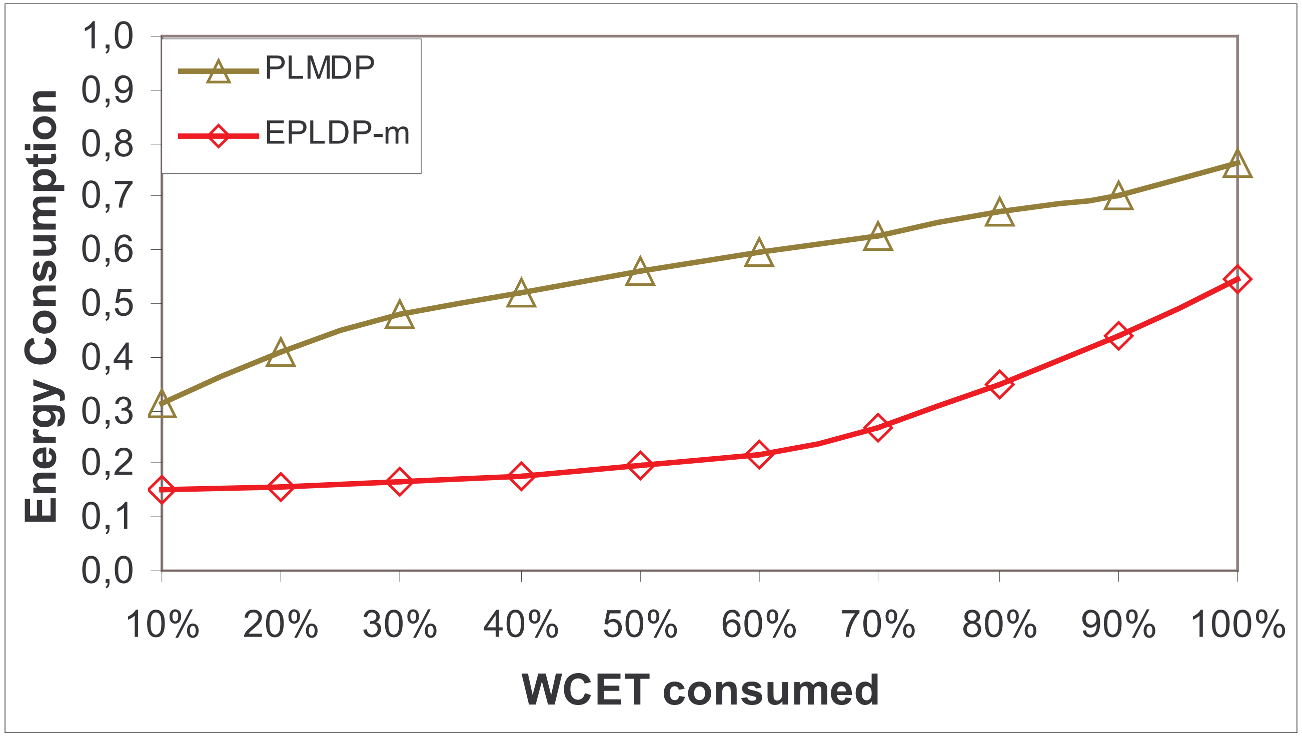
U=90%

Task workload:

Min 10%

Max 20%

INS task set benchmark



6 tasks

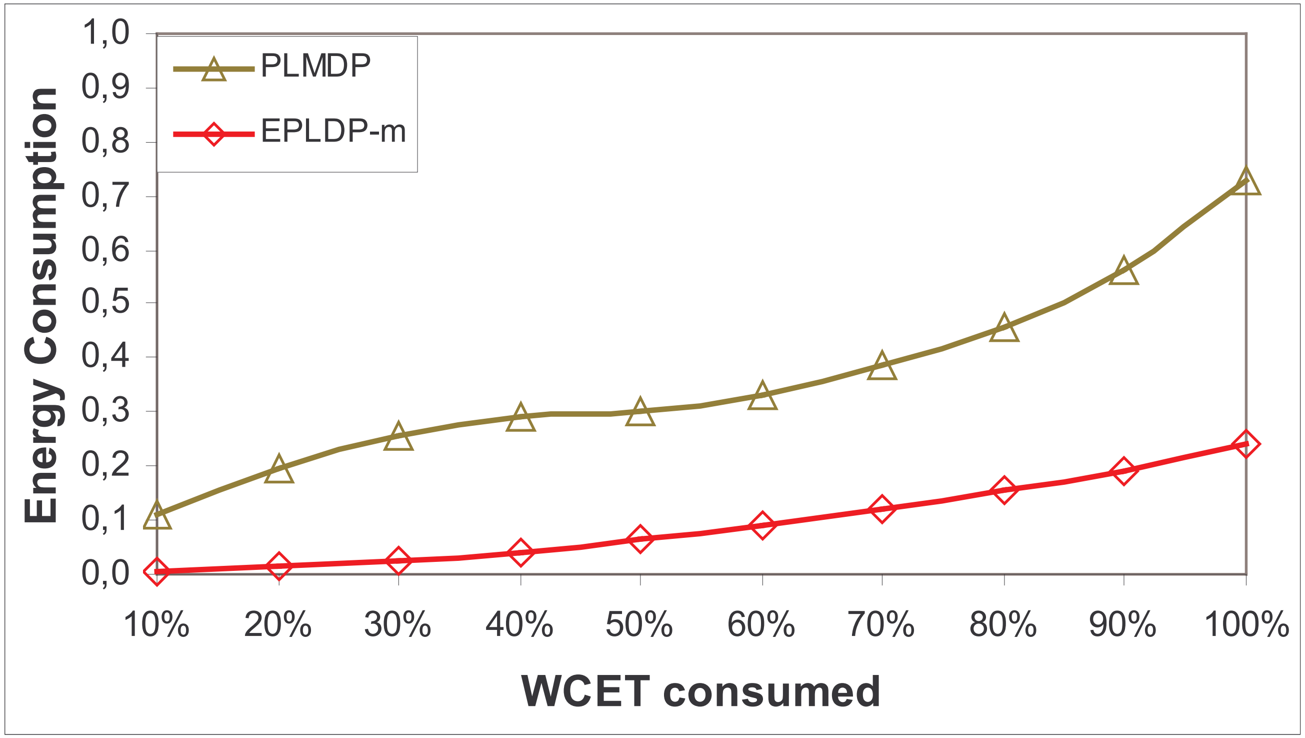
U=74%

Task workload:

Min 16%

Max 47%

CNC task set benchmark



8 tasks

U=48%

Task workload:

Min 1,5%

Max 15%

Mean Energy Consumption Comparison

	Avionics	INS	CNC
• LPFPS*	97%	63%	91%
• PLMDP	77%	56%	30%
• EPLDP	79%	41%	22%
• EPLDP-m	35%	27%	9%

* Y. Shin and K.Choi,"Power conscious Fixed Priority scheduling in hard real-time systems" DAC99, New Orleans, Lousiana, ACM 1-58113-7/99/06,1999.

Conclusions

- The Enhanced Power Low Dual Priority scheduling obtain significant energy savings without missing the tasks deadlines
- The EPLDP improves PLMDP whenever a moving average is used to determine the real % of WCET used