CPU Consumption, from Real-Time Embedded Systems to Mobile Devices

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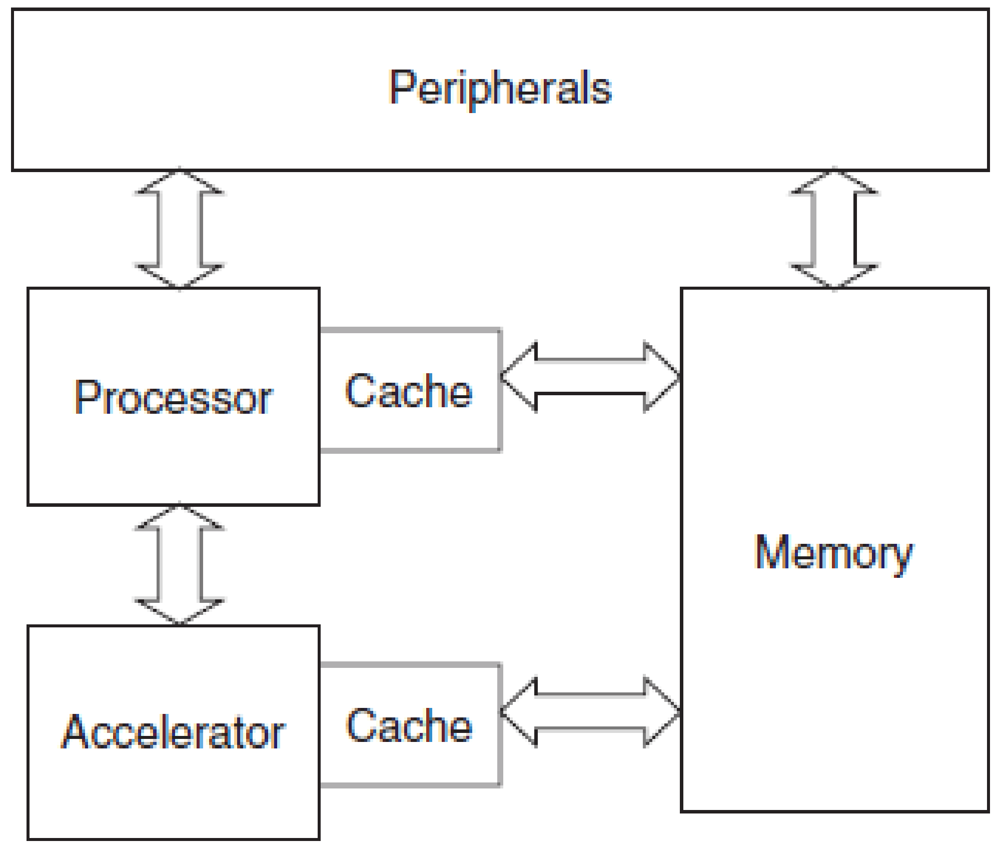
CPU Consumption, from Real-Time Embedded Systems to Mobile Devices

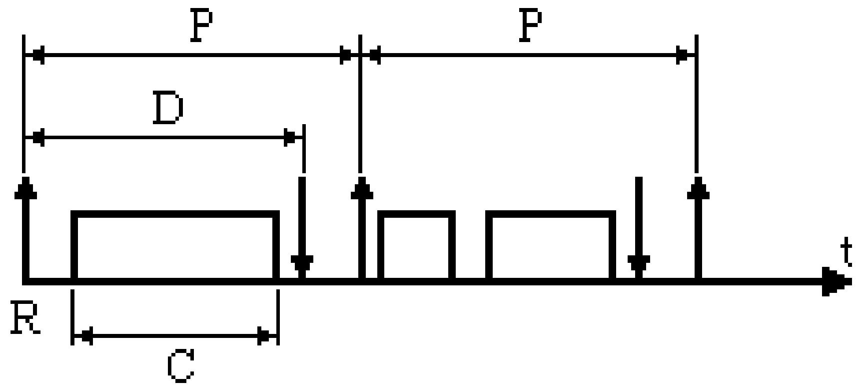
1. Optimal task scheduling
2. Task scheduling and minimal CPU consumption
3. Computing hardware of mobile devices



- Conclusion

1. Optimal task scheduling

Task – duration, cost, activation, deadline, period



Feasable scheduling, optimal scheduling, optimal scheduler

[DER 74] *EDF – UP optimal for premptible and independent tasks*

[MOK 83] *EDF – non MP optimal*

[MOK 83] *Impossibility of optimal on-line scheduler for tasks with mutual exclusion constraints*

1. Optimal task scheduling

[DER 89] – *necessar and sufficient conditions for UP scheduling*

- feasibility of periodical, independent tasks,

with same deadline and period

[DER 89] insufficient knowledge problem *for optimal MP scheduling for tasks based on deadlines (without* apriori *complete knowledge on task duration, deadline and activation)*

[DER 89] – *conditions for feasible MP scheduling of independent tasks*

1. Optimal task scheduling

[MNA 59] – for some metric, MP scheduling based on a finite number of preemptions is better than non-preemption

[GAR 75] – difficulty of non-preemptive MP scheduling for different models of tasks with the same deadline

[LAW 83] – MP preemptive scheduling with minimal delayed task is NP-hard

[GRA 76] – for a feasible model of tasks, changing initial conditions can give worst time of scheduling

Theoretical studies based on statistical analysis of the task parameters.

2. Task scheduling and CPU consumption– theory

[CHA 92], [BRO 95], [BRE 95], [CHA 96], [TIW 98] – minimizing the power consumption by minimizing the voltage

=> technological evolution

=> not possible on-line

[MAL 94] - Intel DX2-486, 40Mhz

[LEE 96] - DSP Fujitsu CMOS, 40Mhz

[HON 99] - aproximation of the power consumption as a polynomial function of the CPU speed

=> at the same number of CPU cycles, the power consumption is dependent on the instructions used

2. Task scheduling and minimal CPU consumption

$g(S) = S^p,\ p \geq 2,\ p \in \mathbf{R}$ [YAO 95] <u>periodical independent tasks</u>

$g(S) = \sum_{j=1}^{r} a_j S^j,\ r \in \mathbf{N},\ r \geq 2,\ a_j \in \mathbf{R},\ \forall j = 1,\ldots,r$ [AYD 01]

$$\begin{cases} \min \sum_{i=1}^{n} \sum_{j=1}^{P/P_i} E_i\left(S_{ij}\right) & (1) \\ \sum_{i=1}^{n} \sum_{j=1}^{P/P_i} \frac{C_i}{S_{ij}} \leq P & (2) \\ S_{\min} \leq S_{ij} \leq S_{\max} \qquad i = 1,\ldots,n \qquad j = 1,\ldots,\frac{P}{P_i} & (3) \\ \text{feasible scheduling with } \{\mathrm{S}_{\mathrm{ij}}\} & (4) \end{cases}$$

[AYD 01] - UP static solution - same speed – maximal CPU capacity

- UP dynamic solution – on-line speed adjustment

[VIL04] - EDF optimal for power consumption

- general formula for tasks speed

2. Task scheduling and minimal CPU consumption

periodical independent tasks

[VIL04] - generalisation for MP with variable speed

- necessar and sufficient condition for the feasibility

$$\max_{i=1,\ldots,n}\left(\overline{C}_i \big/ D_i\right) \le S_{MAX}$$

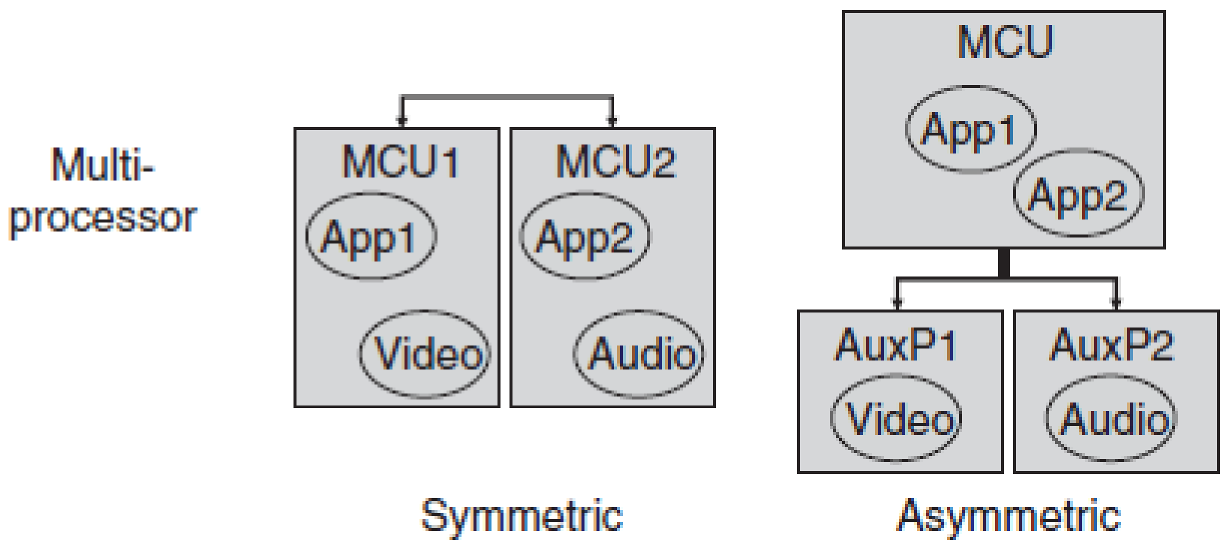
- task migration not efficient
- existence of a global optimal scheduling
- uniformity principle
- minimizing the power consumption by augmenting the number of the processors

$$\frac{1}{2^{r-1}} E_1 \le E_2 \le \frac{1+2^r}{3^r} E_1$$

- algorithm for evaluating the power consumption for a set of periodical independent tasks

3. Computing hardware of mobile devices

[CHA02] - typical signal processing task on a RISC machine (StrongARM, ARM9E) requires three times as many cycles as a C55x DSP while consuming more than twice the power



[MAK07]

- Integrating all of the subsystems into one chip

3. Computing hardware of mobile devices

Symmetric multiprocessing (SMP)

=> balance load between each other [VIL04] – energy saving

=> save energy by shutting down some of them when the load is low

- multiprocessing can be a relatively complex solution - [VIL04] not necessary task migration
- processor-level granularity as basis of energy management?? [MAK07]
- [VIL04] theoretical important energy gain for same type of tasks
- [TEG11] experimental proof for energy gain

Asymmetric multiprocessing

- multiple specialized pieces of hardware
- eased design
- allocating tasks to different pieces of equipment

Conclusion: **Combining the two approaches**

3. Computing hardware of mobile devices

[TEG11] - beginning of 2011: multi-core CPUs (Tegra 2 – nVIDIA) - tablets and smartphones;

NVIDIA's Project Kal-El – vSMP – fifth CPU core (ARM Cortex A9) individually enabled and disabled based on the work load

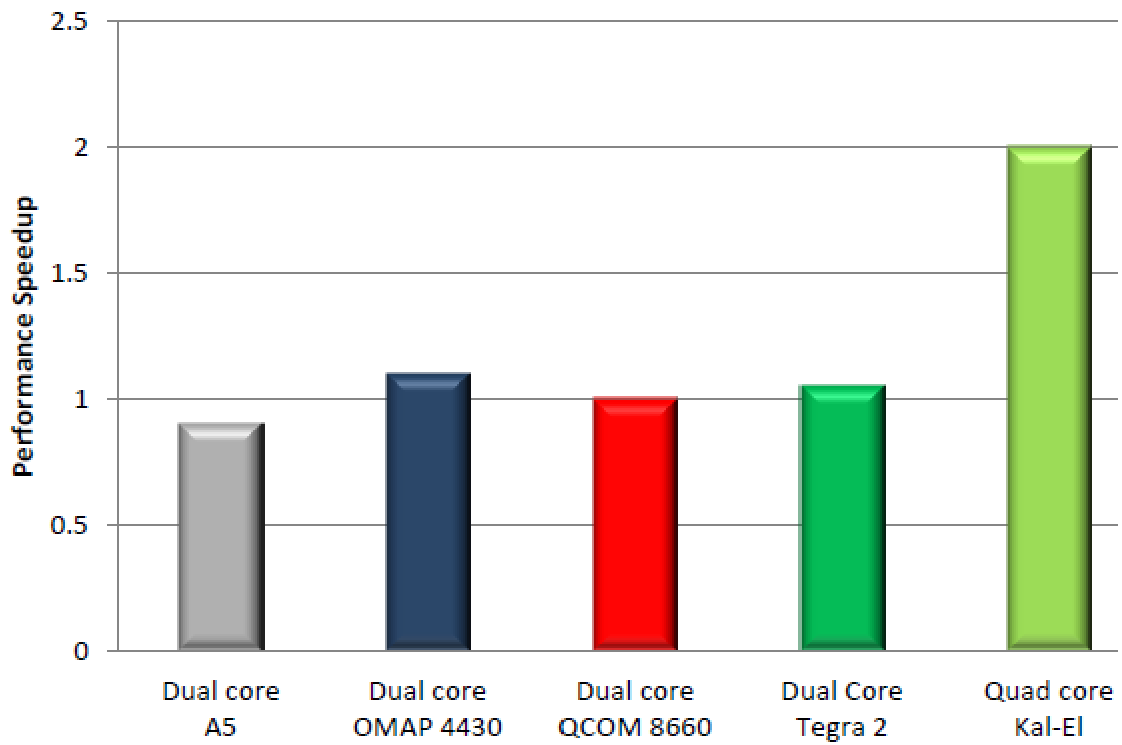
=> lower power consumption, higher performance per Watt than dual-core

[TEG11]

CoreMark

Benchmark

Results



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[TEG 11] nVIDIA Whitepapers: *Benefit of Multiple CPU cores in Mobile Devices*, *The Benefits of Quad Core CPUs in Mobile Devices*