Energy-Aware Synthesis of Fault-Tolerant Schedules for Real-Time Distributed Embedded Systems

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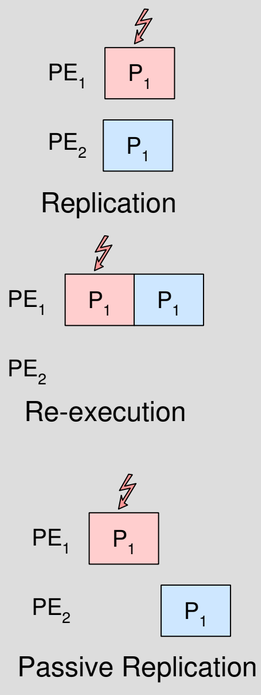
Reliability-Aware Energy Optimisation for Fault-Tolerant Embedded MP-SoCs

Fault-tolerance

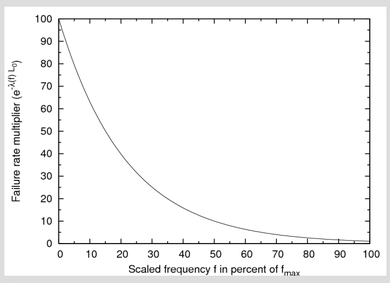
- Faults are tolerated by using temporal or spatial redundancy, or a combination of the two
- Fault detection is done using well known techniques such as: timing and bit coding



Energy vs. Faults

- Recent research[1] shows that the probability of transient/soft faults increases dramatically when decreasing the voltage of a circuit
- Many modern designs uses dynamic voltage scaling (DVS) to minimise energy consumption
- Fault-tolerant systems that use power management techniques may prove to be fault-tolerant but unreliable due to increase in faults
- Relation between faults and voltage is given by[1]:

$$\lambda(f) = \lambda_0 10^{\frac{d(1-f)}{1-f_{min}}}$$



Relation between voltage and failure rate

[1] D. Zhu et al.: "Reliability-Aware Energy Management for Periodic Real-Time Tasks", 2007

Summary

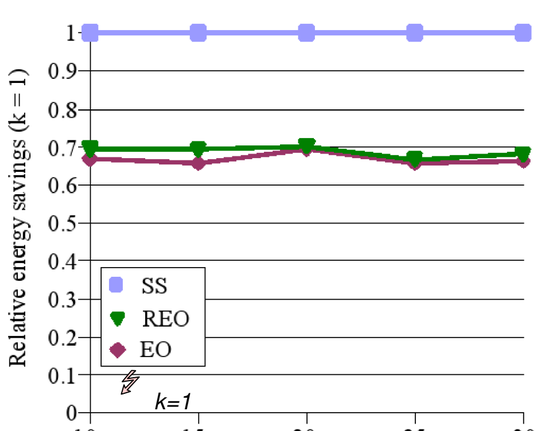
- Design optimisation tool for distributed embedded real-time systems
- Decides mapping, fault-tolerance policy and fault-tolerant schedule
  - Hard real-time,
  - Hard reliability goal,
  - Static schedule for processes and messages,
  - Fault-tolerance for *k* transient/soft faults
- Optimise for minimal energy consumption
- While considering impact of lowering voltages on the probability of faults
- Constraint logic programming (CLP) based implementation

Fault-tolerant scheduling

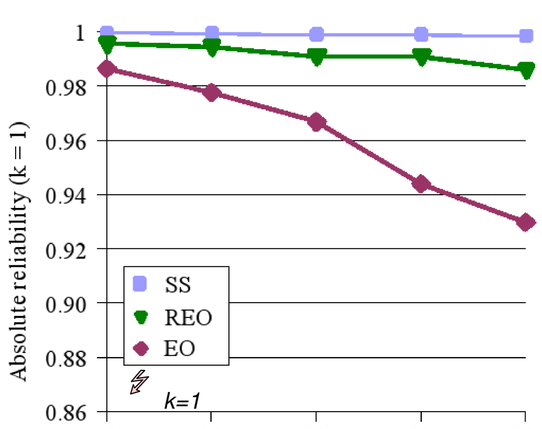
- More complex scheduling schemes yield more slack for energy management
  - Trade-off transparency for performance
  - Performance, and hence the obtainable energy savings are greatly increased
- More complex schemes demand larger schedule tables to be stored in the processing elements, and more sophisticated online schedulers

Reliable energy management

- System reliability is affected by use of energy management
  - The use of DVS increases the probability of faults, thus damaging the system reliability
- Reliability *must* be considered in the optimisation process
  - Considering reliability in the optimisation process allows for finding the minimum energy schedule that meets the reliability goal
  - Reliability is imposed as a constraint
- Reliability can be met at very little energy cost
  - Considering the reliability while optimising enables us to find reliable schedules with comparable energy savings

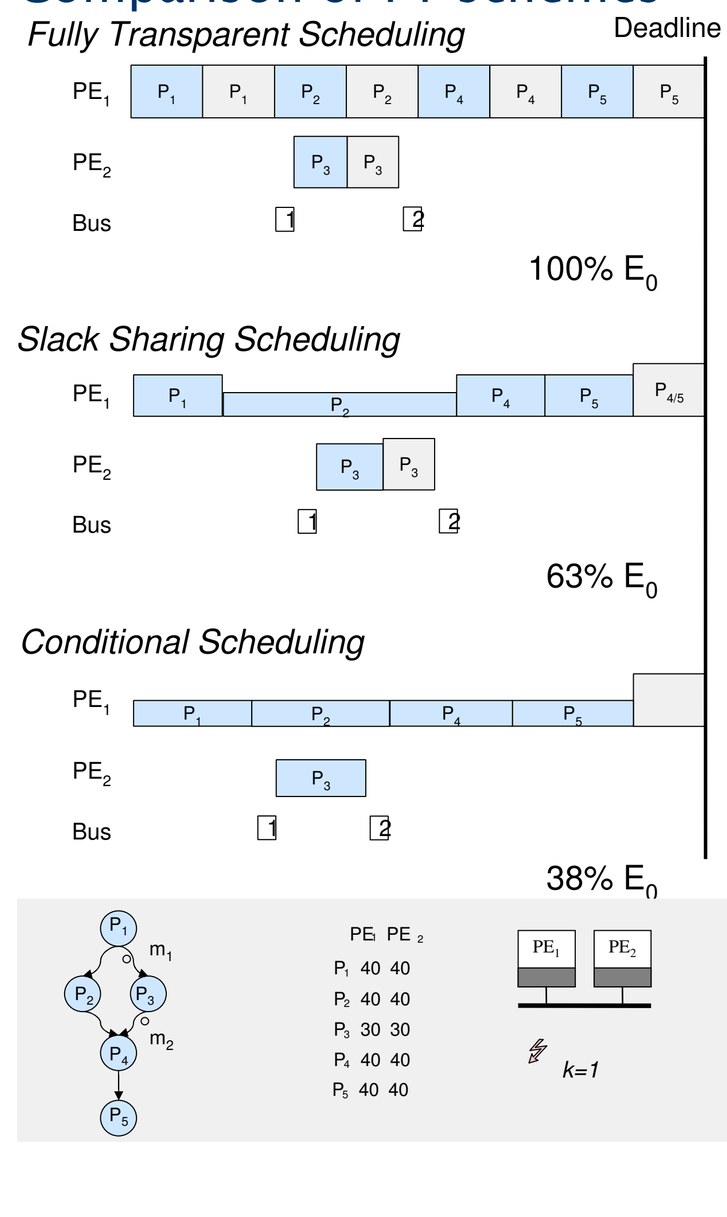


Comparison of energy savings



Comparison of system reliability

Comparison of FT schemes



Energy vs. reliability