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

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 & 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 FT schemes

- Fully Transparent Scheduling
  - PE1: P1, P2, P3, P4, P5, P6
  - Bus 1: 100% E0
- Slack Sharing Scheduling
  - PE1: P1, P2, P3, P4, P5, P6
  - Bus 2: R=0.999 999 987
  - PE1: 63% E0
- Conditional Scheduling
  - PE1: P1, P2, P3, P4, P5, P6
  - Bus 3: R=0.999 999 878
  - PE1: 38% E0

Energy vs. reliability

- Straightforward (SS)
  - PE1: P1, P2, P3, P4, P5, P6
  - Bus 4: R=0.999 999 987
  - PE1: 100% E0
- Energy optimisation (EO)
  - PE1: P1, P2, P3, P4, P5, P6
  - Bus 5: R=0.999 999 878
  - PE1: 68% E0
- Reliable energy optimisation (REO)
  - PE1: P1, P2, P3, P4, P5, P6
  - Bus 6: R=0.999 999 900
  - PE1: 73% E0

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 use 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:\(^1\):

\[
\frac{\lambda}{\lambda_0} = A \cdot 10^{-\frac{V}{V_{max}}}
\]


Reliability vs. number of processes

Comparison of energy savings

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<th>Number of processes</th>
<th>Energy Savings</th>
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Comparison of system reliability

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<th>Reliability</th>
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