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

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

Energy vs. Faults

- Recent research 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:

Relation between voltage and failure rate


Comparison of FT schemes

<table>
<thead>
<tr>
<th>Fully Transparent Scheduling</th>
<th>Slack Sharing Scheduling</th>
<th>Conditional Scheduling</th>
</tr>
</thead>
<tbody>
<tr>
<td>PE₁, PE₂, PE₃, PE₄, PE₅, PE₆</td>
<td>PE₁, PE₂, PE₃, PE₄, PE₅, PE₆</td>
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<td>Bus 1, 2</td>
<td>Bus 1, 2</td>
<td>Bus 1, 2</td>
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<tr>
<td>Deadline</td>
<td>100% E₀</td>
<td>63% E₀</td>
</tr>
</tbody>
</table>

Energy vs. reliability

- Straightforward (SS): R=0.999 999 987, 100% E₀
- Energy optimisation (EO): R=0.999 999 878, 68% E₀
- Reliable energy optimisation (REO): Rₑ, imposed as hard constraint, Rₑ=0.999 999 900, 73% E₀