Low-Power Reliable Real-Time Embedded Systems

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1 Introduction

Real-time embedded systems research in the last decade has been marked by a growing interest in *power/energy management* issues due to proliferation of pervasive/portable devices and drastically-increased power densities. Based on the *Dynamic Voltage and Frequency Scaling (DVFS)* technique, various schemes have been studied to save energy while still meeting the timing constraints for different real-time task models and scheduling policies.

A traditionally important avenue in real-time systems research is *fault tolerance:* faults must be detected, and appropriate recovery operations must be completed before the task deadlines in safety-critical systems. The dominant majority of the run-time faults fall into the category of *transient faults*, which could be recovered from using *backward recovery* techniques (e.g., using roll-back recovery). Transient faults have become more common recently with the aggressive use of scaled technology sizes and reduced design margins to achieve high performance. Recenly, it was shown that the use of DVFS in low-power real-time systems increases significantly the rate of transient faults [5].

Therefore, it becomes clear that there is an urgent need to design energy management schemes that are cognizant of implications/needs for real-time system's correct operation in the presence of transient faults.

2 Reliability-Aware Power Management

In our preliminary study [1], we have proposed a *reliability-aware power management (RA-PM)* scheme. Instead of using all available slack time for power management as in ordinary power management, to recuperate the reliability loss due to power management, the scheme reserves part of the available slack to schedule an additional recovery block before applying the remaining slack for saving energy. We have shown that, with the help of the additional recovery block, RA-PM can preserve system reliability while achieving significant energy savings.

RA-PM was further extended to consider multiple tasks sharing a common deadline, where the optimal slack allocation for maximizing energy savings in the reliability-aware settings was shown to be NP-hard [2]. Based on EDF scheduling, we have also investigated RA-PM schemes for periodic real-time tasks [4]. In addition to task-level utilization-based static schemes, based on a novel dynamic slack management mechanism that could conserve the slack reserved for recovery blocks across preemption points, job-level dynamic schemes are also proposed [4].

3 Future Work

Considering the fact that reduced energy consumption of DVFS could lead to lower operating temperatures, the negative effects of DVFS on transient fault rates could be *mitigated* to some extent. Thus, we plan to develop an *integrated energy and reliability management framework*, that incorporates various fault-inducing factors, task models (e.g., aperiodic, periodic and mixed workload) and scheduling policies (e.g., EDF and RM) at different sophistication levels (e.g., static, dynamic and/or adaptive). Moreover, the framework will be extended to *lifetime-aware systems* that must remain functional during a mission with a non-replenishable *fixed* energy budget.

As the next generation processors, *chip multiprocessors (CMPs)* provide great opportunities for embedded system design, in particular, thanks to the parallel nature of embedded applications (e.g., sensor data processing and video/audio encoding). CMPs have also been explored for fault tolerance in addition to high performance and energy efficiency, as they inherently provide hardware redundancy. Based on our preliminary study on the energy and reliability tradeoffs using process-level and thread-level duplication techniques [3], we will further investigate the use of CMPs in real-time embedded systems design, for performance, energy and reliability.
For more information, please visit the project website http://www.cs.utsa.edu/~dzhu/projects/lprc.html.

References

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