Task scheduling in an energy harvesting WSN for Structural Health Monitoring

Project Proposal

The process of monitoring structures for the purpose of damage identification is known as Structural Health Monitoring (SHM). SHM can be done for periodic lifetime or steady state monitoring to verify the structural integrity over the time. In the event of extreme incidents such as an earthquake, SHM can be used for rapid event assessment to provide reliable information about the integrity of the structure at the request of an external trigger.

The adoption of wireless sensor networks in advanced SHM systems has increased significantly in the last few years. A common and efficient method to extend the overall lifetime of a SHM node is to use a solar energy harvester (EH). The goal of such a system is to complete a sequence of tasks within a designated period of time, given the limited and unreliable energy supply from the EH, while adhering to the various constraints, such as energy, time and accuracy. Recent work has looked at ways to meet these constraints. Moser et al.[1] presented a scheme using discrete service levels associated with specific rewards under only an energy constraint. Steck et al.[2] designed a binary search algorithm to meet the task deadlines with multiple constraints acting simultaneously. The main limitation of this algorithm is that it is conservative in its usage of available energy; thereby limiting the scheduler from achieving the maximum number of SHM measurements.

To overcome these limitations, we propose a task scheduler that aims at maximizing system performance within the various constraints; specifically improving the average accuracy of a SHM measurement, number of measurements performed and number of external requests that are serviced. The task scheduler will be implemented using a regression model algorithm with a DVFS feature, which is designed to help scale the energy costs vs accuracy while processing. These contributions are explained briefly as follows:

1. **Regression model based algorithm:** The goal of this algorithm is to maximize the number of SHM measurements and average accuracy of a measurement within various constraints. Active SHM measurement starts with actuation and sensing, which are performed recursively over all the possible pairs or paths of piezo-electric transducer (PZT) sensors. This is followed by averaging the multiple samples in each path, which reduces the uncorrelated noise. Thus, a higher number of SHM measurements, translates to a greater reduction in uncorrelated noise; thereby improving SHM accuracy.

   The technique used in the regression model based algorithm is as follows: The number of PZT paths (n) is mapped to each of the constraint parameters such as energy, time and accuracy. A regression model is then obtained through curve-fitting. This model is used to dynamically vary the task complexity and distribution over time in order to perform the optimal task scheduling, within the energy limit.

2. **Dynamic Voltage and Frequency Scaling (DVFS):** DVFS is well known technique of lowering clock speed and supply voltage to achieve large savings in energy with a modest performance loss. The energy measurements for the different DVFS clock speeds are obtained from the embedded platform performing structural health monitoring i.e. SHiMmer. The SHiMmer node is capable of running at two different active frequency modes. Based on the knowledge of the amount of available energy and the complexity of SHM tasks, the proposed algorithm selects the optimal DVFS working condition for the system. Operating in the DVFS mode allows for energy savings. This surplus energy is used to increase the rate and number of SHM measurements, translating to an increased average accuracy of a SHM measurement.

To validate the proposed algorithm, a SHM task scheduler will be simulated. The inputs to the system will include: (i) A real distribution of solar energy comprising sunny, cloudy and variable weather conditions. (ii) A SHM task sequence or task graph (iii) The various measurement thresholds and system characteristics from SHiMmer.

The task scheduler will be demonstrated to be efficient for not only steady state SHM operations run at a pre-defined schedule, but also for sporadic external requests. The DVFS enabled scheduling algorithm will be tested for its ability to maximize system performance within the various constraints; specifically its capability to improve the average accuracy of a SHM measurement, number of measurements performed and number of external requests that are serviced.

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1. Clemens Moser, Lothar Thiele, and, Jian-Jia Chen “Power management in energy harvesting systems with discrete service levels”. In ISLPED ‘09: Proceedings of the ACM/IEEE conference on International symposium on low power electronics and design, 2009