A Review Of Different Types Of Schedulers Used In Energy Management

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Abstract - ***Recent technological advances have greatly improved the performance and features of embedded systems. With the number of just mobile devices now reaching nearly equal to the population of earth, embedded systems have truly become global. These tendencies have also made the task of managing their power consumption extremely challenging. In recent years, several techniques have been proposed to address this issue. Dynamic voltage and frequency scaling (DVFS) is a widely studied power management method, which has a goal to reduce the energy consumption by dynamically varying the CPU frequency or the supply voltage. Real-Time DVFS (RT-DVFS) is a branch of DVFS, which reduces CPU energy consumption through DVFS, while at the same time ensures QoS by developing proper real-time task schedules. The paper presents the review of various DVFS scheduling algorithms which offer different approaches to utilize the CPU idle time to vary the frequency or the supply voltage and also different energy saving techniques to meet the critical power requirement.***

Key Words: *scheduling, DVFS, WCET, Energy Consumption, online, offline*

1. INTRODUCTION

Energy consumption is a critical design constraint for real-time embedded systems. Usually, embedded application should be real-time, which means a task must complete its execution before some deadline. A hard real-time system does not allow any failure in meeting the deadline, while a soft real-time system has a relatively weaker constraint. Thus, in order to meet the critical power requirement in embedded systems, various power-aware algorithms have been proposed.

Dynamic voltage scaling (DVS) was first introduced by [1].The objective of being power-aware in execution gave rise to DVS processors. In [1], the best scheduling principle bases on a region spanned by a given task specification. A task is arranged only when it can be run at the lowest processor frequency. The voltage and frequency of a processor has a linear relationship, and processor scaling is usually via frequency scaling. There are two power-saving situations: one is that no urgent real-time task exists and the other is that the processor is executing memory-bound instructions. Formula below illustrates the power saving reason:

$$P_{dynamic} \sim \alpha C V^2 f$$

α and C are constants, V denotes the voltage and f denotes the processor frequency. It is seen that reducing the processor frequency has a quadratic influence of the voltage while has a cubical influence of the power, due to the linear relationship of voltage and frequency of a processor.

In this paper, the need of power management is taken into consideration in embedded systems and survey is done of several research works on scheduling algorithms which are aimed at improving energy efficiency of embedded systems.

A schedulability analysis is important to decide if a set of tasks can be arranged and, if so, how to schedule the tasks. The schedulability analysis is the core element in any scheduling algorithm. A weak schedulability analysis indicates a scheduling algorithm performing poorly. It is common to use a response-time analysis to determine the schedulability of a set of tasks. The idea in this analysis is to compute every task's worst-case response times and compare that with its deadline. The worst-case response time is not necessary equal to a task's worst-case execution time, since response times take the waiting time when a task is preempted into account. Scheduling algorithms is divided into offline and online scheduling algorithms.

1.1 Offline scheduling algorithm

Offline scheduling algorithms use static analysis to arrange all tasks. There is no cognizance of past and future tasks. All tasks are arranged based on their worst-case execution times and once they are scheduled, the task of the algorithm is over. The scheduler follows the schedule, if a task during runtime of the real-time system finishes earlier than it's WCET, the CPU does nothing and there will be a period of no activity on the CPU.

1.2 Online scheduling algorithm

Online scheduling algorithms are different from offline scheduling algorithms, by making their decisions in hurry while the real-time system is not idle. Online scheduling algorithms have a record of already executed tasks. But they do not know about the tasks in the future.

Knowing the past and having an idea of which tasks are ready to be executed makes opportunities for the online scheduling algorithm to be smart. The actual execution time becomes available for the scheduling algorithm, so it can make decision which take advantage of the slack period, such that the response times of various task get reduced.

2. ENERGY AWARE SCHEDULING TECHNIQUES

Figure 1 represents the structure of a feedback-DVS scheme. It has a feedback controller, a voltage-frequency selector and an EDF scheduler. The feedback controller calculates the error from the difference between the actual execution time of a task and C_A, the execution time of the first portion of each task . The voltage-frequency selector chooses a voltage/frequency level according to the error and the best schedule profile. The error is used to adjust the estimation of the execution time for the next task. The best schedule

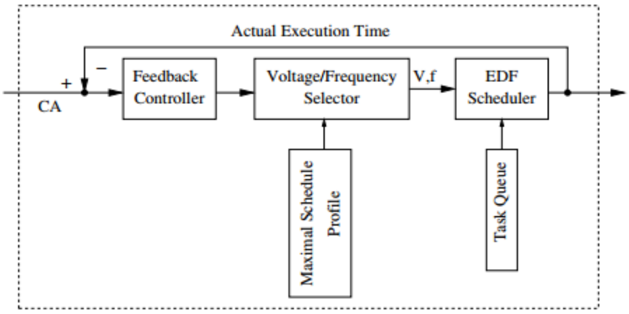

Fig -1: Feedback DVFS scheme [2]

profile includes a running framework of the task set from the start time 0 to the end of a hyperperiod. It is generated offline assuming each task's actual execution time always equals its WCET. The voltage-frequency selector uses the information in the best schedule profile to choose the right voltage-frequency level without missing any deadline. As long as a voltage/frequency level is known, the EDF scheduler arranges the next ready task at the specific processor speed. Tasks are arranged according to EDF policy, i.e., the task with the earliest deadline is given the highest priority. The actual execution time of each task is then fed back to the feedback controller for later decision making.[2]

In [3] Xian et al. present an approach for scheduling in multiprocessor systems to save energy. For scheduling periodic real-time tasks, their approach uses EDF scheduling to make certain the meeting of deadlines of all tasks and thus minimizing energy consumption. A polynomial time heuristic method is presented as the problem is NP-hard. This problem is solved assuming that unbounded and continuous range of frequencies are available. Later, the work is changed so that maximum frequency and the bounded discrete frequencies are available.

Niu et al. in [4] propose an approach to economize leakage and dynamic energy in embedded systems by affiliating DVFS and PPM. In the case when processor is active, the approach chooses a processor speed such that the dynamic and leakage power consumption are balanced.

Awan et al. in [5] evaluates an algorithm for saving energy in embedded systems using multiple low-power modes. The method determines the break-even time for each mode using offline analysis. As early completion of high-priority task creates slack, their technique accumulates this task and uses it to save extra leakage energy in lower priority tasks by allowing the device to stay in low-power mode for longer time.

In [6] Kianzad et al. use genetic algorithm to integrate task scheduling and voltage scaling under a single iterative optimization loop. The method searches for the solution space to find a function and ordering of tasks on each processing element and generates a schedule such that deadline constraints are met and the power consumption is optimized. Further, their approach administers the slack proportionately to different tasks and uses DVFS to save energy. They propose techniques for saving energy in both homogeneous and heterogeneous multiprocessor embedded systems.

In [7], authors present an online greedy scheduling algorithm for independent tasks. The algorithms attempts to reduce energy consumption by ordering task execution so that devices can have continuous long idle periods to be shut down. Moreover, reducing the number of device on/off shrinks transition delays between device operating states. Unlike most real-time DPM techniques which are CPU-enteric

Authors in [8] propose UTilization Based (UTB) algorithm by combining energy harvesting awareness, DVFS, and task slack management to reduce energy consumption of periodic tasks. They proposed a low-complexity task scheduling algorithm which is based on the concept of task CPU utilization – defined as the worst-case task execution time divided by its period

In [9] An extended list-scheduling algorithm is used to reschedule the scheduled tasks. At every step, the scheduler computes energy saving of a task when it is scheduled at the current step and the next step. The energy difference of these two steps are represented as the task's energy saving. Then a task with a higher energy saving and lower slack time gets higher priority to be scheduled.

In [10] J. Luo and N. K. Jha have proposed an intra-task voltage scheduling algorithm based on a static timing analysis. In this technique, a given task is divided into several subtasks, and then suitable supply voltage (resulting from static timing analysis of previous segments and based on worse-case execution time of the task) is assigned for each segment. This method has a high energy reduction ratio by utilizing the idle time, and choosing suitable voltage/frequency to occupy these idle times to the fullest.

In [11] Minimizing execution time in MPI programs on an energy-constrained, power-scalable cluster, R. Springer et. al select an upper limit for energy usage. Further a coalition of performance modeling and performance prediction is used to lower execution times with respect to their predefined upper limit. After the models are generated for both execution time and energy consumption, important parameters are calculated by implementing a task for few times and then giving back the computed parameters. For better computation, the following steps were iterated until a appropriate arrangement is accomplished: (1) using models to predict each possible scheduling of tasks, (2) executing the task a few times and (3) updating computed parameters.

3. CONCLUSIONS

In this paper, we have presented several novel schedulers for realtime dynamic voltage scaling. A common property of the surveyed scheduling algorithms is that they all depend on supervising of what is going on in the hardware and in applications, and choosing the best resource allocation policy based on that information. RT-DVS is applicable widely in general real-time systems. The energy savings works well for extending battery life in portable applications.

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