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Energy Harvesting Issues In Real-Time System

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***Abstract*—Today the world is getting more complicated with the use of embedded system. Real-time based embedded systems are widely used everywhere. But the problem in today's real-time embedded system is limited power supply due to the compactness of the system . Many technologies are invented to cope-up energy need of mobile devices system .Energy harvesting easy is free energy solutions for such system. Still there is wide area of research in this field. Up till no optimum solution has focused to satisfy the energy requirement of the real-time system using energy harvesting. This paper discusses the various energy harvesting issues related to the real time system with the implementation of EDF algorithm.**

Keywords*—*energy harvesting, real-time system, earliest deadline first

I. Introduction

Real-time embedded system is the demanding field in the computer industry. Daily new products are coming to the industry. This includes battery powered mobile devices starting from laptop to mobile phones. The devices may used for various multimedia data processing such as audio, video, images and other types of data. Like traditional desktop system, requires continuous power supply for their functioning. Normally desktop system is provided power supply on the wall. There are some situations providing the power supply from the wall is not possible to mobile devices. Portable electronic devices, in which power is given by batteries, rely on energy efficient power management scheduling algorithm to increase the battery lifetime; while non-portable system need energy efficient schedule to reduce the energy cost. Several strategies are used such as changing the battery and providing continuous power supply from the wall. But for remote devices cost of battery replacement is high and regular power is not also possible. An important strategy to achieve energy saving is via dynamic voltage scaling (DVS) [1], which enable a processor to operate at a range of voltage and frequencies. Meikang Qiu *et al.* [2] design a novel loop scheduling algorithm for real–time applications that produce schedule consuming minimal energy. Energy harvesting provides solution to this type of system. Energy is power required by the system for their functioning. Energy for the harvesting available nearby everywhere around us such as movement of windows, doors and machine components, wind moment, vibrations of motors. All these activities can be converted in to small amount of energy. However, the energy from these various sources is often found in such small quantity that it cannot supply adequate power for efficient working. The fact is that, up till now it has not been possible to capture such energy sufficiently to perform any useful work. The energy source can be sufficient to provide the power to system. Energy Harvesting is the process of capturing energy from environment energy sources, accumulating them and storing them for later use. An Energy Harvesting Module is an electronic device that can perform various functions to power the system. The various microprocessor based technologies have increased power efficiency, effectively reducing power consumption requirements. Nowadays small solar panels suffice to ensure continued operations, and several photovoltaic (PV) harvesting circuits have been recently proposed for this purpose. The advantage of the solar energy over other forms of environmental energy [3] is that the available solar energy can be predicted at least to some extent. This allows one to implement power management techniques and to plan optimized the future system activity in order to achieve more suitable operations. Another aspect [4] of harvesting system design is to use harvesting energy using appropriate power management approaches. The figure 1 shows the energy harvesting structure of energy from solar panel to scheduling of several tasks with required energy. The energy is stored in the battery and according to the scheduling strategy used for process. This paper deals with the various types of energy harvesting methods used for real-time embedded systems, and also different approaches used to optimization of the energy in the system.

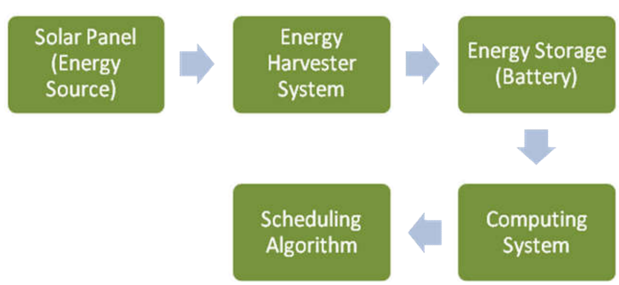

Fig.1. Energy Harvesting System.

II. RELATED STUDY

Energy can be harvested from different sources and may be used by several types of system. Power management is need of computer system design not only hardware structure but also to software side. In [5] Andre Allanena a*t al* considers the task on single processor with variable voltage and frequency. Within a framework problem is solve the task execution using valid schedule within the task deadline **,** with the same battery level at the beginning and end. This uses the idle time using algorithms to recharge the battery at minimum level to execute the task. However this solution deals with the frame based system in a restrictive structure. All tasks have common deadline and also the problem of preemption is not solved. The possibility to harvest energy from environment and sustain everlasting operation has earned much interest recently. In [6] address sensor nodes which are situated in an outdoor environment in the sunlight. This algorithm work to maximize the overall reward. The frame based structure is considered and prediction is determined for the future frames for energy estimation. In [7], G. Sudha *et. al.* Uses complex periodic task for scheduling in a single hope wireless network, in this each node supports dynamic voltage scaling and dynamic power management techniques respectively**.** But the problem mentioned in this research work gives the solution using analytical approaches such as integer linear programming formulation. The lazy scheduling algorithm (LSA) proposed in [8] as clairvoyant algorithm, assume the knowledge of future availability of environmental power. The algorithm work on offline task schedule. To achieve efficient use of energy resources the algorithms lazy scheduling algorithm (LSA), the solution is energy-aware lazy scheduling algorithm (EA-LSA) proposed in [9]. But the computational complexity is not reduce up to the extend and scope is remain for the improvement.

III. SCHEDULING IN REAL-TIME SYSTEM

This section provides an up-to-date assessment of available energy harvesting methods suitable for real-time embedded system.

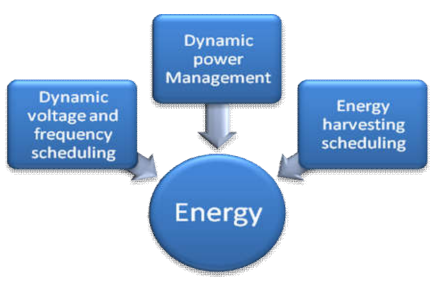

Fig.2. Different techniques used for energy supplier in the system.

The Table 1 gives the introductory survey on energy harvesting as applied to relevant themes in mobile devices.

Embedded systems are design to performance in high and accurate scale when needed, but most of the time; their components operate at utilization less than 100%. Figure 3 shows the effect of several techniques on the energy. Dynamic voltage and frequency scheduling (DVFS) lower down the execution whenever required. The Dynamic power Management (DPM) decreases the energy consumption by idolizing the components. The techniques in [10] have limitations in energy harvesting system because they minimized CPU power.

TABLE I. OVERVIEW OF VARIOUS APPROACHES OF SCHEDULING.

Different approach for energy utilization	Scheduling Techniques	Remark
Rechargeable Batteries	Fix speed processor variable speed processor	To be able to reduce the cycle time of the system
Energy-Aware Scheduling	Dynamic voltage scheduling and Dynamic Management Scheduling-Dynamic modulation scheduling	Energy minimization not only of processor but entire system
Reward Maximization	Polynomial –time algorithm	Minimize battery capacity, to minimize round-trip losses
Dynamic and Leakage Energy Minimization	Loop-Scheduling algorithm	To produce scheduling consuming minimal energy, minimize leakage power consumption
Approximation algorithm for variable voltage processor	Dynamic Voltage Scheduling	Energy minimization max throughput
Energy efficient dynamic voltage and frequency	Weighted First Come First Serve scheduling	Using resource constraints, work on energy saving
Energy-aware LSA	Clairvoyant Algorithm	Reduce the LSA computational complexity, test is performed on varying energy capacity
Semi-online Earliest deadline first based	Optimal Scheduling	Provide feasibility test, uses slack energy

We consider a real-time task set in a renewable energy environment defined by a set of n periodic and independent tasks {T1, T2……Tn}. Each task Ti is characterized by its priority pi, its worst case execution time ci, its period pi, its deadline di and its worst case energy consumption ei. The execution time ci and the energy consumption Ei of a task are fully independent, for example considering two tasks Ti and Tj , we can have $c_i<c_j$ and $e_i>e_j$ .We will assume that $0 < c_i \leq d_i \leq p_i$ for each $1 \leq i \geq n$. We consider here di=ti i.e. deadline of the task is equal to its period.

Most of the real time task scheduling algorithm implements earliest deadline first algorithm, which follows one acceptance test that the processor utilization should be less than one i.e. Up<1 other wise task set will not be schedulable successfully. The processor utilization is given by,

The processor utilization as,**Error! Reference source not found.**

In the scheduling while considering the energy constrain its energy utilization[11,12] is calculated first as follows,

The energy utilization as, **Error! Reference source not found.**

The energy utilized by each task is given by *ei uses* energy from the storage E. The capacity of E within the boundaries Emax - Emin gives the total energy storage in the system. The energy in the storage used later for task execution without considering any leak.

Algorithm: Earliest Deadline First with Energy Constraint

Step 1: Find processor load Up,
If Up< 1
Execute Task set
End if

Else
Discard Task set
End else

Step 2:Find task scheduling sequence according to their shortest deadline first,
For every ready task Ti, with highest priority,

Do

If Tie<E (t),at time t

Execute task Ti

End if

Otherwise discard task Ti

End for

Step 3: Execute task according to scheduling sequence till timeline = hyperperiod.
Step 4: End.

Consider the periodic task set T1 (2, 5, 7), T2 (1, 7, 9), T3 (3, 10, 11) characterized by computation time, deadline and energy. All tasks are arrived at time zero and scheduled by earliest deadline first algorithm[13,14,15]. Processor utilization for three tasks is 0.84 and energy utilization is 0.66. The energy utilization is 0.66 which should be < charging rate hence we have consider initial charging rate i.e. *pr*=1.

Initially the battery capacity, we assume Emax=10 and Emin=0. The task feasibility is checked before its execution on the energy basis, if the sufficient energy is available in the battery then task is executed successfully and it is feasible. With three periodic tasks with charging rate *pr*=1 and Emax=10 schedule by EDF without idle time as shown in figure 3.

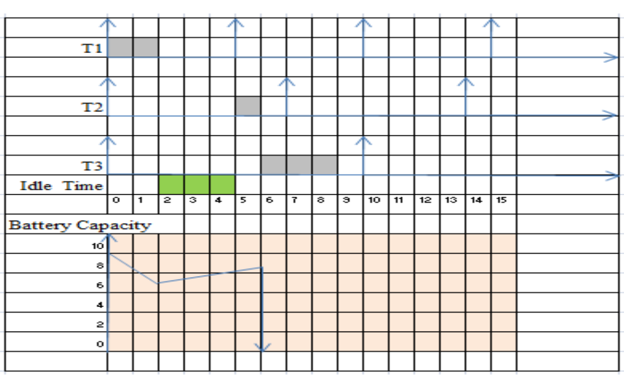

Fig. 3 Task schedule using EDF with *pr*=1 and Emax=10 with idle time.

After energy calculation of task T1 and T2,

T1: E (0) = 10 – 7 + 1(2) = 5

T2: E (2) = 5 – 9 + 1(1) = - 3

With increase battery and charging rate *pr*=1 and Emax=20 without inserting idle time shown in figure 4. After calculate the energy for T1, T2 and T3,

T1: E (0) = 20 – 7 + 1(2) = 15
T2: E (2) = 15 – 9 + 1(1) = 7
T3: E (3) = 7 – 11 + 1(3) = - 1.

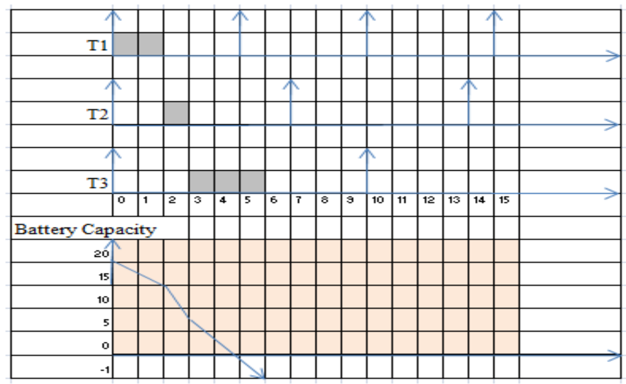

Fig. 4 Task schedule using EDF with *pr*=1 and Emax=20 without idle time.

Our aim is find the optimal charging rate and battery capacity for the tasks to execute it successfully with missing its deadline due to the energy shortage. Hence we are continuously changing the charging rate and battery capacity.

Now the charging rate is set to pr=3 and battery Emax=20. As shown in figure 5 all task are executed successfully without missing any deadline and energy shortage. In this execution idle time inserted at time 9 boosts additional energy for task T1 and task T3 is also executed successfully leaving sufficient energy in the battery at time 15.

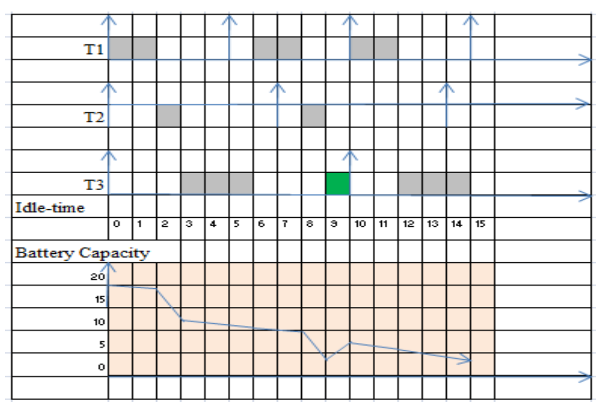

Fig. 5 Task schedule with *pr*=3 and Emax=20 with idle time.

T1: E (0) = 20 – 7 + 3(2) = 19

T2: E (2) = 19 – 9 + 3(1) = 13

T3: E (3) = 13 – 11 + 3(3) = 11

T1: E (6) = 11 – 7 + 3(2) = 10

T2: E (8) = 10 – 9 + 3(1) = 4

T2: E (9) = 4 – 0 + 3(1) = 7 with inserted 1 idle time at time 9.

T1: E (10) = 7 – 7 + 3(2) = 6

T3: E (12) = 6 – 11 + 3(3) = 4

IV. CONCLUSION

Energy is the major concern of real-time embedded system; various approaches are used to improve the performance of the power management. This paper discusses some of them to put the focus on the problems related with efficient power utilization technique. It is observed that no optimum solution has been found with the effective use of energy in to the system. The research area is open for the development of power management and efficient uses of energy. Also the parameters related with energy harvesting and its utilization to keep it up to the mark. Another aspect of harvesting system design is to take advantage of energy available in the environment which is always neglected. The conventional device with traditional power supply wont aware so much about energy management policies, it never compromise on power supply. But the problem arises where giving continuous power supply is not possible. Today is the need of new power management strategies considering mobility of the system and energy need to improve the system overall performance. Real time system uses the energy in the system for their task execution. Scheduling the task with EDF algorithm gives significance result to improve the execution range in the system. The implementation of EDF uses the idle time to gain the additional energy required for the task execution.

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