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Scheme for Tolerating Single Transient Fault in Time Critical Applications with Optimal Checkpoint and Energy Constraint

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Abstract:

The approach proposed is to find optimal number of checkpoints for tolerating single transient fault in real time critical applications. Optimal numbers of check points are calculated in the consideration of energy as constraint. Deadline of the task is also affect the number of checkpoints. In the proposed approach we find the minimum execution time with checkpoints. If this is lesser then the deadline then the number of checkpoints are optimal, otherwise the task can not be scheduled. The approach is also suitable for finding optimal number of checkpoints with minimum energy consumption. The energy minimization is achieved by using DVS (Dynamic Voltage Scaling). We apply our algorithm on both static and dynamic voltage. It was found that the proposed approach is minimized energy on dynamic voltage level as comparison to static voltage level.

Keywords: Fault Tolerance; Check Pointing; Energy Constraints.

Introduction:

The success of many real time critical applications such as space missions, nuclear reactors, defense systems, air-traffic control systems, etc. are highly dependent on their correct functioning (logical operations are giving expected services) within its deadline. Some of real time applications are battery driven having energy as constraint. These systems such as tin sensor nodes are dependent on battery power. The task running on a real time system requires meeting deadline. So this real time system having following constraints:

a) Deadline
b) Performance
c) Fault tolerance
d) Power consumption

Deadline of a real time system means the time where the operation completes with logically correct result. We can measure the performance of a system by checking logical correctness of result with respect to its deadline. Fault tolerance is the method to give the desired result in presence of fault in real time critical applications with energy constraint. Energy minimization is one of the factors affecting life of the system. The Fault tolerance technique in this system should be efficient. The efficiency of a system can be achieved by various parameters such as deadline, lower power consumption, etc. The system is said to be more efficient if the finishes the process on its deadline with minimum energy consumption.

Related Work:

Dynamic Voltage Scaling (DVS)

In 1999, I. Hong, D. Kirovski, G Qu, M. Potkonjak, and M. B. Srivastavaproposes An energy-aware DVS method for scheduling real-time tasks while using energy harvesting techniques [3].

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Energy Aware EDF Scheduling

In 2009, Guohui Li, Fangxiao Hu, and Ling Yuan propose an energy-efficient scheduling algorithm (TDVAS) using the dynamic voltage scaling technique to provide significant energy savings for clusters. The TDVAS algorithm aims at judiciously leveraging processor idle times to lower processor voltages (i.e., the dynamic voltage scaling technique or DVS), thereby reducing energy consumption experienced by parallel applications running on clusters. Reducing processor voltages, however, can inevitably lead to increased execution times of parallel task. The salient feature of the TDVAS algorithm is to tackle this problem by exploiting tasks precedence constraints [4].

Fault tolerance with power management

In 2004, ChaeseokIm and Soonhoi Ha propose a fault tolerant schedulability analysis for aperiodic tasks and derive the optimal number of checkpoints presented. The optimal number of checkpoints can help the task to guarantee the timing constraints and minimize the worst case execution time in the presence of faults. A scheduling scheme which carries out dynamic voltage and frequency scaling (DVFS) on the basis of the schedulability analysis for the problem of static task scheduling and voltage allocation is proposed. The problem is addressed and formulated as a linear programming (LP) problem. A transient fault is typically achieved through online fault detection, check pointing, and rollback recovery [5].

Research Objective:

Fault tolerance is a typical policy for system reliability in real-time systems [1][2].

The time critical systems which are functioning logically correct within its deadline also required fault tolerance to give desired results. The objective is to apply optimal number of checkpoints to tolerate single transient fault in such system with energy constraint. This approach considered a single transient fault which can be tolerated at run time to get desired output. This work proposes a check pointing scheme by which we find optimal number of checkpoints which can tolerate the fault with minimum execution time and minimum energy consumption. This proposes a suitable algorithm for finding optimal number of checkpoints used to tolerate single transient fault on static as well as dynamic voltage level.

Methodology:

In proposed approach following operations will be formalized

a) Optimal Number of Checkpoint
b) Energy minimization

Algorithm

Given system schedule a set of aperiodic task T = { T_1; T_2; T_3; :::; T_n} with task attribute

Ti = <a_i; e_i; d_i>, i = 0,1,2,..., (n-1), on uniprocessor with EDF at different supply voltage level V = {V_1; V_2; V_3; :::; V_n} where each voltage level is associated with its corresponding speed and each voltage level gives discrete power consumption. The energy consumption for each task is depends upon supply voltage and frequency.

Proposed Fault Tolerance Technique

In this we propose a new check pointing approach for tolerating single transient fault in real time system. In this work we will calculate optimal number of transient fault. The optimality of checkpoints depends upon deadline of task and speed of processor.

Optimal Check pointing Algorithm

The proposed algorithm is divided into three parts. First algorithm calculates optimal number of checkpoint by using rest of two algorithm for calculating checkpointing and energy for each task. The proposed algorithm can tolerate fault with minimum energy consumption.For finding optimal checkpoints, the algorithm works as given below:

Algorithm 1 Algorithm for Cal_ energy(Ti)

Begin

1. Let E_c is total capacity of battery

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2. Find E_c^i, energy available for task T_i
3. Calculate $E_d^i = \int E_{dput}$, $T_i \varepsilon Q$
4. $E_c^{i+1} = E_c^i - E_d^i$
5. Exit

Optimal chkpoint(Q): We have a set of aperiodic task Tm with its deadline dm and execution time em. At time t = 0, we take the tasks arrived and sort them on the basis of deadline. Now take the smallest deadline task Ti and apply Cal_ Chk and Cal energy algorithm to calculate number of checkpoint and energy consumed for that task. Then we calculate the finishing time Fi of that task Ti. Now at t = Fi find the number of tasks arrived and then sort these tasks on the basis of deadline and again calculate number of checkpoint by Cal_ Chk and energy consumed by Cal energy.

Cal_Chk: This algorithm gives the optimal number of checkpoint to tolerate single transient fault. Here we initialize number of checkpoint n = 1, and checkpoint overhead r = 1. Then we calculate finishing time Fn of each task Ti start with minimum voltage V where n is number of checkpoint.Compare this value with previous value of n. If this value is less than or equal to the previous value then increase n by 1 and repeat the same until condition unsatisfied. Again compare this value with deadline of the task and also check the availability of energy. If both conditions are satisfied, n-1 are the optimal number of checkpoint. Otherwise increase the voltage and apply Cal_Chk until get optimal number of checkpoint. If no condition is satisfied results no checkpoints can be applied here.

Cal_energy: Energy is important parameter for any real time system. So a fixed battery as an energy source is applied.

Algorithm 2 Algorithm for Optmal_ Chkpoint(Q)

Begin

1. Set a queue Q of ready task T_m
2. While (true) do
3. **3.** At t = 0
   $d_1 = \min\{d_m : t_m \varepsilon Q\}$
4. **4.** Cal_ Chk(T_i)
5. **5.** Cal_ energy(T_i)
6. **6.** Find finishing time F_i of task T_i
7. **7.** At $t = F_i$
   $d = \min\{d_m : T_m \varepsilon Q \ \&\& \ a_m <= F_i\}$

if ($d_{i+1} = F_I$)

Cal Chk(T_i)

Cal energy(T_i)

Else

Remove task from Queue Q

8. **8.** Go to step 6
9. **9.** Exit

Algorithm 3 Algorithm for Cal_Chk(Ti) With Static Voltage

Begin

1. Let n = 1, r = 1, V = Maximum voltage
2. Calculate for task T_i
3. Find $F_n = e_i + n_i * r + [e_i/n_i] + \Sigma j \varepsilon Th_i [e_j + n_j * r + [e_j/n_j]]$

4. Compare F_n, F_{n-1}

if ($F_n <= F_{n-1}$)

Do n = n + 1

5. Go to step 3

Else

6. If ($F_n <= d_i \&\& E_d^i <= E_c^i$)

Print n-1, optimal number of checkpoint

Else

Print, task can not be scheduled

7. Exit

Algorithm 4 Algorithm for Cal Chk(Ti) With Dynamic Voltage

Begin

1.Let n = 1, r = 1, V = minimum voltage

2.Calculate for task Ti

3. Find $Fn = ei/pk + ni*r/pk + [ei/ni] + \Sigma j \varepsilon Thi[ej/pk + nj*r/pk + [ej/nj]]$

4. Compare F_n, F_{n-1}

if ($F_n \leq F_{n-1}$)

Do n = n + 1

5.Go to step 3

6. If ($F_n \leq d_i \&\& E_d^i \leq E_c^i$)

Print n-1, optimal number of checkpoint

Else

Increase voltage level V, upto maximum

Go to step 3
Else
Print, task can not be scheduled
7. Exit

Conclusion:

There are various approaches for transient fault tolerance with energy. Many of the real time applications are fixed battery operated and some are chargeable battery operated. Tolerating a transient fault in fixed battery operated critical real time applications with energy minimization is a big issue. In this thesis we presents a checkpointing approach for tolerating single transient fault in real time critical applications where source of energy is fixed a fixed battery. In this work we find the optimal number of checkpoint with minimum energy consumption.The proposed algorithm is capable of performing better in the scenario when the battery is of fixed size.

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