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# Fault Tolerance Issues in Real Time Systems with Energy Minimization

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## Abstract

Real time systems are very frequently systems used in today scenario. All real time systems should be efficient and generate appropriate result even though there is fault in the system. Fault is very basic to occur in a system. As most of these systems work in fault prone environment, a task running in these systems should be finished on its deadline. Fault tolerance is the technique to give the required output in the presence of fault which can be achieved by different methods. Fault tolerance can be achieved by checkpointing to overcome the problem of total re-execution. In this paper we will discuss the issues and their solutions such that a task running on real time system finish on time with minimum energy consumption. The energy minimization can be achieved through dynamic voltage scaling (DVS).

**Keywords**: Real Time System, Fault tolerance system, DVS.

## 1. Introduction

The successes of many real time applications such as space missions, nuclear reactors, defence systems, air-traffic control systems, etc., are highly dependent on their correct functioning within its deadline. Some of the system are battery driven having energy as constraint. These systems such as tiny sensor nodes are dependent on battery power. The task running on these systems requires meeting deadline. 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 factor affecting life of the system. The Fault tolerance technique in these systems 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 it finishes the process on its deadline with minimum energy consumption.

### 1.1 Real Time System

Real Time Systems are those systems which are depend not only on logical correctness of output but also depend upon deadline of task. Every task running on real time system has a deadline. It may be soft, hard, or firm. A task running on real time system should finish on or before its deadline. If the task is not finishing on deadline then results may vary which may be useless after its deadline. Real time system can be categorized on the basis of deadline such as: [3] [4]. Every real time system requires some energy to operate. The executions of task are also depends upon availability of sufficient energy. If there is no sufficient energy then it is not possible to operate the system which result the failure of system.

### 1.2 Fault

A fault in real time system can result a system into failure if not properly detected and recovered at time. These systems must function with high availability even under faults. A fault is a defect in a component or design of the system. There are three types of fault as follows [2]:

i. *Permanent:* These faults occur by accidentally cutting a wire, power breakdowns and so on. These faults can cause major disruptions and some part of the system may not be functioning as desired.

ii. *Intermittent:* These are the fault appears occasionally in the system. Mostly these faults are ignored while testing the system and only appear when the system goes into operation. Therefore, it is hard to predict the extent of damage these fault can bring to the system.

iii. *Transient:* These faults are caused by some inherent error in the system. However, these faults are corrected by retrying or roll backing the system to previous safe state such as restarting software or resending a message. These faults are very common in Real time systems.

### 1.3 Dynamic Voltage Scaling (DVS)

Dynamic voltage scaling and dynamic frequency scaling (DVFS) allow adjusting processor voltage and frequency at runtime. Usually, higher processor voltage and frequency leads to higher system throughput while energy reduction can be obtained using lower voltage and frequency [5][10][11][12][13]. In DVS technique [10][11][12][13][14][15], the processor executes each task at various frequencies in such a way that the task is executed within its deadline and also the energy utilization is minimized.

The power consumption can be represented by:

$P \alpha V^2 f$

Where V is supply voltage and f is system clock frequency. This relationship between power and voltage shows that reducing the voltage results in reducing the power consumption. An energy-aware DVS method for scheduling real-time tasks while using energy harvesting techniques is presented in [7].

### 1.1 Issues

In general, fault tolerance is the technique to give the required services in the presence of fault or error within the system. The aim is to avoid failures in the presence of faults and provide services as per requirement. In fault tolerance the fault is detected first and then recovered without participation of any external agents. The main issue in fault tolerance is: how, where, and which technique is required to tolerate fault in the system. As we know many types of fault and failure can arrive on a system, so there should be an appropriate method which can tolerate such problem.

## 2. Related Work

Fault tolerance is a typical policy for system reliability in real-time systems [1][2][3][4][5][6]. Fault tolerance computing refers to the correct execution of user programs and system software in the presence of transient faults. It is typically achieved through online fault detection, checkpointing, and rollback recovery [16]. Power management can be achieved at various design levels. There are two main types of dynamic power management (DPM) techniques. The first includes selective shut-off or slow down of system components that are idle or underutilized [6]. The second, which is often termed as dynamic voltage and frequency scaling (DVFS), refers to the dynamic control of the supply voltage level for the various components in a system [7]. Several approaches have analyzed the effects of checkpointing in real time scheduling algorithms and proposed optimal solutions for the placement of the checkpoints [10], [11], [17], [18]. However, the timing and energy parameters of the checkpointing have not been analyzed in the past for real-time systems.

An offline reliability-aware power management scheme is presented in Zhu et al. (2008) for real-time tasks with probabilistic execution times [8]. The scheme puts aside just enough slack to guarantee the required reliability while leaving more slack for energy management to achieve better energy savings. In [13][16][17], 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 DVFS on the basis of the schedulability analysis for the problem of static task scheduling and voltage allocation is proposed in [6][7].

## 3. Task Model

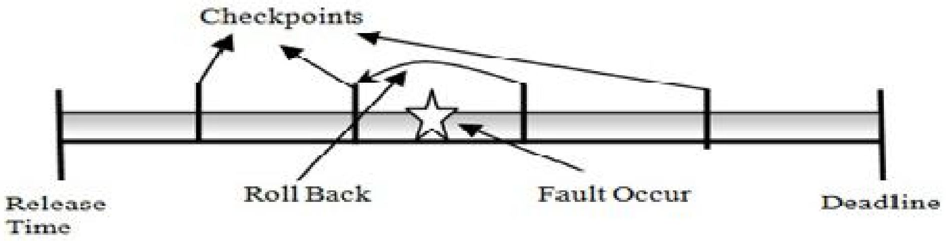
In real-time system, at maximum CPU speed the following terms are included. The task model consist a set of aperiodic task T = {T1, T2, ... ,Tn } . Each task is independent and having its own worst case execution time and deadline on maximum speed. Each task consists of three parameters < ai, ei, di >, where ai is arrival time of task, ei is worst case execution time at full speed and di is deadlines. Here, we will consider individual task in the task set, and start time of the first task can be considered at 0 and d can be assumed as the time interval in which the task can be executed. For the sake of simplicity, the maximum speed Pk of the CPU assumed to be 1.

## 4. Processor Model

Here we will consider that only a single task is running on uniprocessor. The components running on this processor are frequency dependent and can operate on discrete voltage level i.e. V={$V_1$, $V_2$, $V_3$ ... Vn} where each voltage level is associated with its corresponding speed and each voltage level gives discrete power consumption. It is assumed that the energy consumption of the processor is dominated by dynamic switching energy [18] The energy consumption of a processor is depends upon the speed of processor.

## 5. Fault and Recovery Model

We assume that at most one specific transient fault, such as any security attacks or environmental noises, may occur during a task life-time, between its release time and deadline. Such faults can be tolerated by total re-execution of the damaged portion of the task, by time-redundancy technique for fault tolerance. However, since the task is real-time, we should avoid of complete task rollback. Therefore, we will use checkpointing techniques. Within a checkpoint, a consistent state of the system is saved onto a stable storage. Moreover, before saving the task state at the instant of checkpointing, an acceptance test is run to discover the possible occurrences of transient faults. Therefore, if a fault occurs, its detection is postponed until the next checkpointing interval. If a fault occurrence is detected, rollback to the last checkpoint is done and the tasks remaining portion is executed by the maximum processor speed. In this regards, the target is to avoid the service unavailability by preventing the deadline of a task to be missed.



## 6. Energy Model

Energy is basic requirement for operating a real time system. The energy consumption for processing a task can be explained as below. Here we have a fixed size battery to operate a system. On processing each task some amount of energy is drain between the interval *t*1 and *t*2 by given equation

$$E_d^i = \int_{t_1}^{t_2} E_{dput}, T_i \in Q$$

$$E_c^{i+1} = E_c^i - E_d^i$$

*t*1 and *t*2 are the task execution starting time and task finishing time respectively. After processing each task the available energy can be calculated by equation below. This available energy is then used to process next task.

## 7. Proposed Approach

There are many approaches that emphasize on fault tolerance computing and energy minimization but optimal fault tolerance with energy minimization is one of the issues. In this paper will propose optimal checkpointing algorithm for fault tolerance with energy constraint. Checkpointing is the scheme for tolerating fault but the question is how many checkpoints are applied to make the system efficient. So to make a system efficient we have to find optimal number of checkpoint. We will discuss the proposed scheme for single transient fault tolerance in which we will find the optimal number of checkpoint with respect to energy. Energy consumption is again an issue due to small size of battery of real time application. Energy is managed dynamically by DVS. In OUR research, we will apply the concept of energy harvesting which will help to work a system long time. In proposed approach following operations will be formalized

- Finding optimal number of checkpoints on task level when the tasks are aperiodic in nature.
- Finding dynamic voltage and frequency level applied for minimum energy consumption.
- Development of a dynamic scheduling algorithm for tolerating transient fault.
- Scheduling of task using dynamic scheduling algorithm for energy minimization.
- Design an energy harvesting approach for enhancing energy capacity.

The goal of proposed approach is to assign each task an operating frequency so that the total power consumption is minimized while keeping the real-time task set schedulable under fault-tolerant constraint. Fault tolerance is achieved by applying checkpoint on each task and here keeping minimum energy consumption. Optimal number of checkpoints means the maximum number of checkpoint applied on a task and it finishes its execution on its deadline. Energy minimization means minimum energy consumption for execution of task with fault tolerance. The Energy can be harvested from various resources when a tiny real time node is deployed in remote areas.

### 7.1 Proposed Model

Given system schedule a set of aperiodic task T = *{T*1*, T*2*, T*3*, … Tn}* with task attribute *Ti* = < *ai, ei, di* >, we = 0,1,2,..., (n-1), on uniprocessor with EDF Scheduling algorithm at different supply voltage level V = *{V*1*, V*2*, V*3*… Vn}* 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. Minimum energy consumption for each task is calculated by managing speed level of processor.

### 7.2 Proposed Fault Tolerance Technique

In this work, we will propose a new checkpointing approach for tolerating single transient fault in time critical system. Here we will calculate optimal number of checkpoint to tolerate transient fault. The optimality of checkpoints depends upon deadline of task and speed of processor with minimum energy consumption. Here we will start with the analysis of a simplified scheduling scenario where tasks need only energy as computation resource but may execute in zero time. By disregarding the computation resource time, we will focus on the energy-driven nature of the scheduling scenario. As already indicated in the introduction, the naive approach of simply scheduling tasks with the EDF algorithm without fault tolerance.

## 8. System Requirements

Proposed approach can be implemented online and offline. Here we will implement scheduling algorithm offline and then simulate it with existing approach. for implementing our proposed work following system requirements are required:

- A good performance computer system.
- Linux or Windows OS
- Programming Language C++ for Implementation.

## 9. Conclusion

There are various approaches for transient fault tolerance with energy constraint. 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 OUR work we will presents a checkpointing approach for tolerating transient fault in real time critical applications where source of energy is fixed as a fixed battery. In this work we will find the optimal number of checkpoint with minimum energy consumption. The proposed algorithm will be capable of performing better in the scenario when the battery size is fixed as well as chargeable.

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