

Title	適応型スケジューリング方式の実アプリケーションによる評価と改良
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Citation	
Issue Date	2016-03
Type	Thesis or Dissertation
Text version	author
URL	http://hdl.handle.net/10119/13624
Rights	
Description	Supervisor: 田中 清史, 情報科学研究科, 修士

Evaluation and Improvement of Adaptive Real-Time Task Scheduling with Real Applications

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February 10, 2016

Keywords: Real-Time Task Scheduling, TBS, Adaptive TBS, Worst-Case Execution Time (WCET) .

1 Introduction

In recent years, it is becoming common that different types of tasks reside in a system because of the diversification and complication of embedded systems. In such systems, real-time task scheduling algorithms are required for reducing response times of aperiodic executions while maintaining the schedulability of periodic tasks.

In order to reduce response times of aperiodic execution, the method, called Adaptive TBS (ATBS) [3], that uses predicted execution times (PET) instead of worst-case execution times (WCET) for deadline calculation of aperiodic executions in Total Bandwidth Server(TBS)[2] algorithm was proposed. From the evaluation by simulation, it was confirmed that the use of PET can reduce response times of aperiodic executions. However, response times of aperiodic executions are not fully reduced since calculation methods of PET are not optimal. In addition, the effectiveness of the proposed method in actual systems has not been confirmed since the evaluation used only task sets that were generated based on probability distribution.

The purpose of this study is to improve the performance of ATBS algorithm by increasing the accuracy of the prediction of execution times and to evaluate it by simulation with real applications. In this study, MiBench benchmark suite[4] that is for embedded systems is used as real applications.

2 Related Works

TBS is one of scheduling algorithms proposed for task sets consisting of both periodic and aperiodic tasks, and schedules tasks based on Earliest Deadline First (EDF) [1] algorithm. To schedule aperiodic tasks that do not have their explicit deadline by following EDF algorithm, TBS gives tentative deadlines to aperiodic tasks. By calculating the deadline such that CPU utilization does not exceed 100%, schedulability of periodic

tasks is maintained. Absolute deadline d_k of k th instance of aperiodic tasks is calculated by the following formula.

$$d_k = \max(r_k, d_{k-1}) + \frac{C_k^{WCET}}{U_s}$$

r_k is the arrival time of the k th instance, d_{k-1} is the absolute deadline of the $k - 1$ th instance, C_k^{WCET} is WCET of the k th instance, and U_s is the CPU utilization factor by the server which takes charge of execution of aperiodic tasks.

It is essential to use WCET for calculating tentative deadlines of aperiodic tasks so that TBS maintains schedulability of all tasks, but actual execution times are usually shorter than WCET. ATBS uses PET instead of WCET for deadline calculations in TBS to obtain shorter deadline and can make response times of aperiodic execution shorter. When the assumed execution times elapses but the aperiodic execution does not finish yet (this situation is called "underestimation"), schedulability is maintained by recalculating the deadline with WCET.

3 ATBSM

In ATBS, PET is predicted by using actual execution times of past aperiodic executions. For a task that has small change in execution times, this prediction method is effective, but otherwise not effective. If PET is overestimated than the actual execution time, the response time of the aperiodic execution cannot be sufficiently reduced since the deadline cannot be sufficiently shortened. If underestimation occurs, response times cannot be reduced since the deadline has to be recalculated with WCET.

In this study, I propose a method to improve the performance of ATBS by predicting execution times with high accuracy. This method is called Adaptive TBS Modified (ATBSM). ATBSM predicts execution times with high accuracy by using a formula of predicting execution times for individual applications. Deadlines of aperiodic executions are shortened by reducing the difference between actual execution times and PET, therefore response times of aperiodic executions are reduced.

4 ATBSM+dwcet

If underestimation occurs, response times cannot be reduced both in ATBS and in ATBSM since the deadline has to be recalculated with WCET. ATBSM predicts execution times with high accuracy, but it is not always possible that underestimation never occurs.

Therefore, in this study, a method is proposed to reduce the influence exerted by underestimation. This is achieved by using discrete worst-case execution times (dwcet) that is selected according to the value proportional to actual execution times instead of WCET when underestimation occurs. ATBSM using dwcet is called ATBSM+dwcet.

5 MiBench

MiBench is a benchmark suite for embedded systems, and is provided free of charge. To reflect the diversity of the embedded market, MiBench consists of 36 embedded applications classified into six categories. In this study, 27 applications are used for the evaluation. In these applications, a factor that is proportional to actual execution times can be detected.

6 Evaluation

The performance of the proposed method are evaluated by simulation with MiBench applications. Response times of aperiodic tasks and absolute/relative jitters of periodic tasks are measured.

On average for all applications, response times of aperiodic tasks are reduced up to 30.2% by ATBSM compared to ATBS, and up to 31.3% by ATBSM+dwcet compared to ATBS.

Absolute jitters of periodic tasks are reduced up to 15.1% by ATBSM compared to TBS, and up to 15.9% by ATBSM+dwcet compared to TBS. In addition, the prediction method to reduce jitters by predicting execution times with more high accuracy in periodic instances whose execution time is long is applied, and absolute jitters of periodic tasks are further reduced by ATBSM and ATBSM+dwcet. The results of relative jitters show the same tendency as absolute jitters.

7 Conclusion

In this study, two methods, ATBSM and ATBSM+dwcet, were proposed to improve the performance of ATBS. From the evaluation by simulation, it was confirmed that two proposed methods can make both response times of aperiodic tasks and jitters of periodic tasks shorter than existing methods.

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