



Correspondence Article: Counterexample for suspension-aware schedulability analysis of EDF scheduling

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1 Introduction

Self-suspension behavior has been demonstrated to appear in complex cyber-physical real-time systems, e.g., multiprocessor locking protocols, computation offloading, and multicore resource sharing, as demonstrated in (Chen et al. (2019), Section 2). Although the impact of self-suspension behavior has been investigated since 1990, the literature of this research topic has been flawed as reported in the review by Chen et al. (2019).

Although the review by Chen et al. (2019) provides a comprehensive survey of the literature, two unresolved issues are listed in the concluding remark. One of them is regarding the “*correctness of Theorem 8 in (Devi (2003), Section 4.5) ... supported with a rigorous proof, since self-suspension behavior has induced several non-trivial phenomena*”. This paper provides a counterexample of Theorem 8 in (Devi (2003), Section 4.5) and disproves the schedulability test.

We consider a set of implicit-deadline periodic tasks $\mathbb{T} = \{\tau_1, \dots, \tau_n\}$, in which each task τ_i has its period T_i , worst-case self-suspension time S_i , and worst-case execution time C_i . The relative deadline D_i is set to T_i . There are two main models of self-suspending tasks: the *dynamic* self-suspension and *segmented* (or *multi-segment*) self-suspension models. Devi’s analysis in Devi (2003) considers the dynamic self-suspension model. That is, a task instance (job) released by a task τ_i can suspend arbitrarily as long as the total amount of suspension time of the job is not more than S_i .

Devi’s analysis for implicit-deadline task systems is rephrased as follows:

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Theorem 1 (Devi 2003) *Let $\mathbb{T} = \{\tau_1, \tau_2, \dots, \tau_n\}$ be a system of n implicit-deadline periodic tasks, arranged in order of non-decreasing periods. The task set \mathbb{T} is schedulable using preemptive EDF if for all k with $1 \leq k \leq n$ inequality $\frac{B_k+B'_k}{T_k} + \sum_{i=1}^k \frac{C_i}{T_i} \leq 1$ holds, where $B_k = \sum_{i=1}^k \min\{S_i, C_i\}$ and $B'_k = \max_{1 \leq i \leq k} (\max\{0, S_i - C_i\})$.*

Note that the notation follows the survey paper by Chen et al. (2019) instead of the original paper by Devi (2003). Moreover, Devi considered arbitrary-deadline task systems with asynchronous arrival times. Our counterexample is valid by considering two implicit-deadline periodic tasks released at the same time and disproves also the general case.

2 Counterexample for Devi’s analysis

The following task set \mathbb{T} with only two tasks provides a counterexample for Devi’s analysis:

- $\tau_1 : (T_1 = D_1 = 6, C_1 = 5, S_1 = 1)$ and
- $\tau_2 : (T_2 = D_2 = 8, C_2 = \epsilon, S_2 = 0)$, for any $0 < \epsilon \leq 1/3$.

The test of Theorem 1 is as follows:

- When $k = 1$, we have $B_1 = 1$ and $B'_1 = 0$. Therefore, when $k = 1$, we obtain $\frac{B_k+B'_k}{T_k} + \sum_{i=1}^k \frac{C_i}{T_i} = 1$.
- When $k = 2$, we have $B_2 = 1$ and $B'_2 = 0$. Therefore, when $k = 2$, we obtain $\frac{B_k+B'_k}{T_k} + \sum_{i=1}^k \frac{C_i}{T_i} = \frac{1}{8} + \frac{\epsilon}{8} + \frac{5}{6} = \frac{23+3\epsilon}{24} \leq 1$, since $\epsilon \leq 1/3$.

Therefore, Devi’s schedulability test concludes that the task set is feasibly scheduled by preemptive EDF. But, a concrete schedule as demonstrated in Figure 1 shows that one of the jobs of task τ_1 misses its deadline even when both tasks release their first jobs at the same time.

The example in Fig. 1 shows that a job of task τ_1 may be blocked by a job of task τ_2 , which results in a deadline miss of the job of task τ_1 . The counterexample only requires task τ_1 to suspend once. It shows that applying Devi’s analysis in Devi

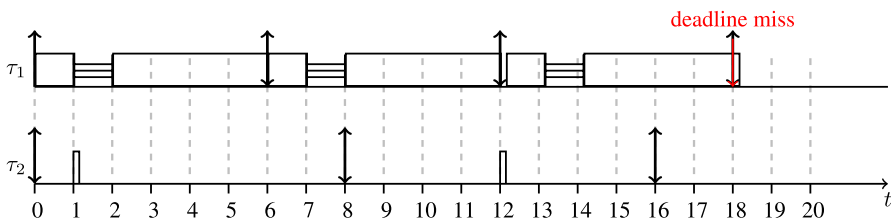


Fig. 1 A concrete EDF schedule with a deadline miss

(2003) is unsafe even for the segmented self-suspension model under EDF scheduling. We note that the above counterexample is only for Theorem 8 in Devi (2003). We do not examine any other schedulability tests in Devi (2003).

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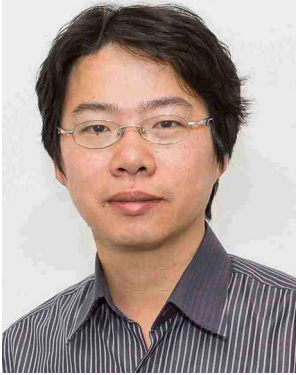
References

- Chen J-J, Nelissen G, Huang W-H, Yang M, Brandenburg B, Bletsas K, Liu C, Richard P, Ridouard F, Audsley N, Rajkumar R, de Niz D, von der Brüggen G (2019) Many suspensions, many problems: a review of self-suspending tasks in real-time systems. *Real-Time Systems* 55(1):144–207
- Devi UC (2003) An improved schedulability test for uniprocessor periodic task systems. In 15th Euromicro Conference on Real-Time Systems (ECRTS), pages 23–32

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