Research on Rate Monotonic Algorithm and Schedulability Analysis in Real-Time System

Shaohui Zhang

School of Network Engineering, Zhoukou Normal University, Zhoukou 466001, China.

ABSTRACT

Rate monotonic scheduling algorithm (abbr. RM) is one of the main algorithms in real-time systems, but its operation efficiency is low relatively. In this paper, two-level scheduling method is used to improve the operational efficiency of RM algorithm, and the basic principle of computer processor in real-time system is analyzed, and the RM scheduling algorithm is implemented concretely. Considering the shortcoming of RM algorithm, a modified RM algorithm based two-level scheduling strategy is proposed. As a result, the performance and reliability of real-time system is increased, and the applicability of the method is widened.

Keywords: Real-Time System; RM Algorithm; Reliability; Schedulability

Correspondence to Author:
Shaohui Zhang
School of Network Engineering, Zhoukou Normal University, Zhoukou 466001, China.

How to cite this article:

Website: https://escipub.com/
1. Introduction
With the rapid development of computer real-time system technology, more and more system applications rely on real-time system as the core control component. In many fields of modern industry, the real-time performance of real-time system is required to process the received information very quickly. Rate Monotonic algorithm (abbr. RM) is a typical static priority scheduling algorithm. [1] It has been proved that RM algorithm is the best among all static priority scheduling algorithms. If there is a task set, it can be scheduled and run under RM scheduling algorithm, and then using RM algorithm, the task set can be guaranteed to execute. This paper designs and improves RM scheduling algorithm for the uniqueness of computer real-time system, and realizes the real-time task management of the system by analyzing the static and dynamic scheduling strategies of tasks. [2]

2. Research Situation and Significance
2.1 Research Situation
Current implementation of RM scheduling algorithm is mainly based on Windows operating system and embedded system. Its implementation methods are different in different systems, but the implementation principle of RM scheduling algorithm is the same. It is realized through analysis of RM scheduling algorithm by various language code algorithms, and the improvement of RM scheduling algorithm has different ideas and ways. [3]

2.2 Research Significance
In order to get real-time computer support, real-time systems must schedule and manage CPU and other resources effectively. However, resource management and scheduling are very complex in multi-task real-time systems. RM scheduling algorithm is often used in real-time systems. [4] The performance of this scheduling algorithm is very good, and it can improve the performance of real-time systems. The analysis and research of RM scheduling algorithm is more conducive to understanding the operation principle of real-time system, so as to continue to improve the RM scheduling algorithm and further improve the system performance. [5]

3. Working Mechanism of CPU Scheduling in Real-Time Systems
3.1 Working Mechanism
The central processing unit (abbr. CPU) is the core component of the computer, which is the heart of the computer. Its main function is to interpret computer instructions and process data in computer software. [6] So CPU plays an important role in computer. At present, preemptive scheduling with priority is generally adopted in real-time systems. In the case of single CPU, when a high priority process comes over, the system has to go through three basic mechanisms to ensure its correct operation, namely queuing, dispatching and context switching mechanism. Queuing is to arrange processes into a queue. Assignment is to take the selected process out of the ready queue, switch the context, and then assign the CPU to it. The context switching operating system needs to save the current context and load the dispatcher. [7]

3.2 Comparisons of Scheduling Algorithms
The essence of scheduling algorithm is to allocate resources. Scheduling algorithms include First Come First Service (Abbr. FCFS) algorithm, Shortest Job First (Abbr. SJF) algorithm, Highest Response Ratio First (Abbr. HRRF) algorithm, Round Robin (Abbr. RR) algorithm, Multi-Level Feedback Queue (Abbr. MLFQ) algorithm, and Static Priority Scheduling algorithm. The advantages of FCFS are su-
itable for long job scheduling, while the disadvantages of FCFS are not suitable for short job scheduling. The advantage of SJF algorithm is suitable for short job scheduling, but its disadvantage is not suitable for long job scheduling. The advantages of HRRF are suitable for long and short job scheduling, but its disadvantage is that the operation complexity is too large.\[8\]

RR Algorithms are usually scheduled to run in time-sharing systems, and it can guarantee the fairness of each task, but it can’t guarantee the strong real-time performance of computer systems. Static priority scheduling algorithms include Rate Monotonic scheduling (abbr. RM) and Deadline Monotonic scheduling (abbr. DM), and their advantages are good predictability and reliability for real-time systems, while their disadvantages are that scheduling algorithms are not flexible enough.

4. Basic Principle and Implementation of RM Algorithm

4.1 Basic Principle of RM Algorithm

RM scheduling algorithm belongs to static priority scheduling algorithm. In the process of scheduling tasks, each task has a cycle, which is fixed.\[9\] And the task has a fixed running time, that is to say, it must be completed in a limited time, and each task has no influence on each other during the running time. In real-time systems, before each task runs, RM scheduling algorithm assigns a priority to each task, which is fixed and unchanged. Priority depends on the duration of the task cycle. The shorter the cycle of each task, the higher its priority and the shorter the time to complete the task.\[10\] This is the advantage of RM scheduling algorithm, but RM scheduling algorithm also has some shortcomings.\[11\] That is, when the code program of real-time system fails or some unexpected bad situation occurs, the task occupies CPU resources beyond the time limit of the task, or even occupies CPU resources for a long time or permanently, so that other low-priority tasks do not occupy CPU resources, leading to starvation.\[12\] In serious cases, it will also lead to general paralysis of computer systems.

4.2 Algorithm Analysis

In 1973, Liu and Layland proposed a sufficient but unnecessary condition, for the periodicity of a task set to be schedulable if the total utilization ratio is less than or equal to \(\frac{n}{2^n} - 1\), and then the task set is schedulable.

\[
\sum_{i=1}^{n} v_i \leq n \left( \frac{2^i}{n} - 1 \right) \quad (1)
\]

Among them, \(v_i = \frac{f_i}{q_i}\), \(f_i\) is the execution time of task \(R\), \(q_i\) is the period of task \(R\). But if the total utilization rate is higher than \(n \left( \frac{2^i}{n} - 1 \right)\), the task set may or may not be scheduled, so this method is not very accurate.

Later and Lehoczky proposed some sufficient and necessary conditions, for a given task set \(G=\{R1, R2, ..., Rn\}\), \(q_1 \leq q_2 \leq ... \leq q_n\), so that

\[
L_i(t) = \sum_{j=1}^{i} f_j \left[ \frac{t}{q_j} \right] \quad (2)
\]

\(t_i = \{kq_j\} \quad j = 1, 2, 3, ..., i; k = 1, 2, ..., \left[ \frac{q_i}{q_j} \right]\)

\(\left[ \frac{q_i}{q_j} \right]\) is the largest integer not exceeding \(q_i/q_j\), then task set \(G\) can be scheduled. \(q_i\) is the period of task \(R\), \(f_i\) is the execution time of task \(R\), \(t\) is the end time of task \(R\), \(n\) is the number of tasks in task set.

5. Improvement and Measures of RM

5.1 Analysis of the Disadvantage of RM

RM scheduling algorithm can guarantee the whole real-time performance of the system. The example also proves that RM algorithm is the best among all scheduling algorithms when task set can be scheduled. If there is a task set
that can be scheduled, then RM scheduling algorithm can ensure that each task runs within its limited time. But RM algorithm has its own shortcomings. If a running priority task takes up CPU resources because of an exception error in the code or an unpredictable exception, it is more likely to take up CPU resources for a very long time or forever. According to the priority of scheduling algorithm, all other tasks with lower priority will starve to death without CPU resources. In severe cases, it may lead to paralysis of the system. So a single scheduling priority algorithm can ensure the real-time performance of the computer operating system, but the reliability of the computer system is greatly reduced, and it can’t adequately prevent some abnormal sudden situations, resulting in the destruction of the scheduling sequence. Then we need to find a scheduling algorithm which can make up for its shortcomings on the basis of RM scheduling algorithm, which is a rather classical static priority scheduling algorithm, to enhance the reliability while ensuring the real-time performance of the computer system.

5.2 Algorithm Improvement

For an operating system, a good scheduling strategy has two points. One is that tasks can occupy CPU resources smoothly and complete tasks smoothly in CPU, and then call out CPU; the other is that when tasks occupy CPU resources for a long time due to exceptions or errors in CPU, they can be forced to terminate the operation of this task, then call out CPU, let other tasks continue to transfer into CPU and continue to occupy CPU resources. After the above analysis of the RM algorithm in the static priority scheduling algorithm and the time slice rotation scheduling algorithm, the advantage of the RM algorithm in the static priority scheduling algorithm is to ensure the real-time performance of the real-time system. It can promote more urgent tasks to run, but its shortcoming is that its reliability is not very high, and it will not prevent higher priority tasks from monopolizing CPU resources. For the time slice rotation scheduling algorithm, it can guarantee fairer scheduling and protect CPU from time isolation. The so-called time isolation is that if a task occupies CPU resources beyond time, then the task will be mandatory out of CPU, so that other tasks can effectively use CPU resources. However, the time slice rotation algorithm can’t ensure the real-time performance of the computer system.

At present, most of the general methods of computer system reliability protection are based on resource reservation or redundant backup. Resource reservation or redundant backup is a very inefficient method of protection. The advantages and disadvantages of RM scheduling algorithm and time slice rotation scheduling algorithm in static priority scheduling algorithm are understood. It is found that their characteristics can complement each other and avoid affecting the real-time performance of scheduling algorithm. At the same time, the reliability of scheduling algorithm can be strengthened. For this reason, this paper adopts a two-tier scheduling mechanism, that is, if a task job occupies CPU resources beyond the time limit, then it will be mandatory to transfer CPU for this task, and then run by other job tasks. Through this way, some abnormal job tasks can be controlled in a small range, thus enhancing the reliability of the computer real-time system. The time slice scheduling algorithm has such advantages. So this paper uses RM scheduling algorithm and time slice rotation scheduling algorithm to combine two scheduling modes,
that is, two-tier scheduling, that is, in the ready queue, two tasks are scheduled, and then the selected tasks are transferred to the CPU. Two different combinations of scheduling algorithms can be combined. The first one is to use RM scheduling algorithm to schedule the task set at the bottom, then a task subset appears, and then a time slice rotation scheduling algorithm is used to schedule the task subset at the top. Then a task result will be allocated CPU resources to run, so that it can be solved. The disadvantage of RM scheduling algorithm is solved. On the contrary, the second one puts the time slice rotation scheduling algorithm in the bottom scheduling and the RM scheduling algorithm in the upper scheduling. The implementation of the two scheduling algorithms is independent successively. The implementation of the two-tier scheduling algorithm makes the reader understand better. It will be clear at a glance in the whole process of running the task. In this two-tier scheduling method, the result of the bottom scheduling method is used for the upper scheduling, but the upper scheduling does not need to know the specific operation process of the bottom scheduling, that is to say, the upper scheduling method does not need to understand the specific operation process of the bottom scheduling. It is said that the underlying scheduling and the upper scheduling do not hinder each other. The upper scheduling only needs to schedule the results of the underlying scheduling. After the upper scheduling, it can be used by CPU to make it run better.

6. Summary
RM algorithm is a classical static priority scheduling algorithm. Before task execution, RM scheduling algorithm assigns a priority to each task. In the process of task operation, the priority of task is fixed, and the priority is determined by the cycle length of each task. The higher priority of a task, the shorter the cycle and the earlier the deadline, this is its greatest advantage, but it also has congenital shortcomings. Through improvement and implementation of two scheduling algorithms, the advantages of time slice rotation scheduling algorithm are used to make up for the shortcomings of RM scheduling algorithm. At the same time, RM scheduling algorithm can also make up for the shortcomings of time slice rotation algorithm, so as to ensure the strong real-time and high reliability of computer real-time system.

References


