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RESEARCH ON REAL-TIME SYSTEM SCHEDULING

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ABSTRACT

With the rapid development of computer technology, as well as the continuous expansion of people's demand for real-time applications, real-time systems are also developing rapidly. At present, the increasing complexity of real-time scheduling problem is related to the diversity of real-time performance requirements. There are many kinds of applications in the objective world, which naturally leads to the diversity of software requirements. Different applications have different requirements for real-time performance, which leads to the system needs to consider their different requirements for real-time performance and provide different resource allocation strategies when allocating computing resources for multiple applications running concurrently. These situations make the scheduling problem of real-time system need to be studied deeply. People have proposed a variety of real-time scheduling methods for different types of real-time systems, including some algorithms and frameworks. A set of theoretical system has been established, and some practical results have been achieved. However, due to the continuous emergence of new application requirements, it is necessary to further develop the real-time scheduling method. In this paper, the research status, existing problems and future research directions of real-time system schedule are described.

Keywords: real-time system; scheduling; open real-time system

1. INTRODUCTION

Real time system originated in the middle of the 20th century, initially closely related to military requirements. With the rapid development of computer technology, real-time system has been widely used in civil fields, such as machinery manufacturing, railway and airport scheduling, aerospace, nuclear power plant and chemical process monitoring, computer multimedia information processing and network applications with QoS (quality of service) requirements. It has become an indispensable part of human social life, "real-time" is becoming a ubiquitous computing.

The emergence and development of real-time system is driven by the actual needs of the real world. Many applications in the real world are related to time factors, such as requiring some operations to be completed before a certain time. Therefore, the computer software designed according to the application needs to meet all kinds of time requirements in the system. One of the main purposes of the related research in the field of real-time systems is to provide a theoretical basis for guaranteeing the time constraints of computing tasks. However, with the increasing complexity of real-time applications, research in this area also needs corresponding development tomeet the actual needs.

2. REAL TIME SYSTEM

For many computer systems, as long as the calculation results are logically correct, they can meet the requirements of correctness. For the real-time system, the correct logical order of instructions and the logical operation results are only one aspect of the problem. There are many descriptions about the concept of real-time system. The following are two representative ones.

1. For any system, if its timely response to external events is crucial, then the system is a real-time system.
2. In real-time systems, the correctness of computing tasks depends not only on the logical correctness of computing results, but also on the time when the results are generated. Therefore, real-time systems are closely related to time constraints. The time constraint here refers to the startexecution time, completion time, deadline of computing tasks, etc.

Usually, the speed of the real-time system to respond to a specific input needs to be enough to control the object that sends a real-time signal; or, the system can respond to the request of an external event in time, complete the processing of the event within a specified time, and control allthe real-time devices and real-time computing tasks to run harmoniously. Typical application systems include: data information processing in radar system, aircraft control system, air traffic control system, MPEG video data compression / decompression, etc. The common characteristic ofthese systems is that they need to complete the task within the prescribed time limit.

3. REAL TIME SCHEDULING

The scheduling problem of real-time system is a key problem related to whether the time constraint can be satisfied. The biggest difference between real-time computing tasks and commoncomputing tasks that only require logical correctness is to meet the relationship between processing and time. Especially in the multi task concurrent system, to ensure that the time constraints of eachreal-time computing task can be met, it is necessary to arrange the execution of the concurrent taskset on the system processor reasonably. Only in this way can we make full

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use of system computing resources to complete real-time computing. So, it involves a key problem of real-time system research: namely real-time scheduling.

The essence of scheduling is a kind of resource allocation, that is, how to reasonably allocate the resources needed for operation among the tasks of the system. Scheduling algorithm determines how the system allocates resources. It is a strategy serving the system objectives. Different scheduling algorithms should be designed for different systems and system objectives. Our common general operating systems, such as windows, UNIX, Linux, etc., in which the design goal of scheduling algorithm is to optimize the average performance of the system, such as fairness, throughput and so on. This design goal is suitable for general desktop computer application and some network server application environment, but not suitable for solving problems in real-time system.

Real time scheduling is faced with different considerations from the original general operating system scheduling, because the success of real-time computing not only depends on the correctness of the logical results, but also ensures that the time of the results to meet the requirements. Therefore, it also emphasizes the time constraint of tasks, and decides when to get what resources to run for a series of tasks. It is an important goal of real-time scheduling to guarantee the real-time performance of each real-time task in the system effectively. The real-time performance here refers to the response time, deadline, miss rate and other time-related indicators.

Because real-time scheduling is one of the important means to guarantee the important characteristics (timeliness and predictability) of real-time system, it is a hot issue in the research ofreal-time system.

4. RESEARCH STATUS OF REAL-TIME SYSTEM SCHEDULING

Real time system originated in the middle of the 20th century and was initially used in the military field. So far, real-time system has penetrated into all aspects of social life [1-5], such as industrial process control, real-time network transmission, automobile control system, etc. In real- time systems, the correctness of computing tasks depends not only on the correctness of the logic of computing results, but also on the time when the results are generated. If the system time constraint is not met, system failure or disaster will occur [6]. Therefore, time constraint is the most basic requirement of real-time system. From the perspective of system structure, in order to ensurethat the time constraint of real-time system is met, two problems need to be solved [7]:

1. Underlying mechanism: mainly consider the time and predictability of each specific operation in the process of real-time task execution. The underlying mechanism is mainly

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related tothe system hardware design.

2. Scheduling mechanism: it is usually reflected in the overall arrangement of the execution time and sequence of multiple real-time applications or tasks by the scheduler of real-time operating system according to various real-time applications and the time urgency of tasks (here task refers to the software entity that completes a specific function, which is a basic unit of real-time scheduling. A task set composed of multiple tasks is called an application). Scheduling mechanism involves real-time system scheduling theory, operating system related theory and so on.

The scheduling mechanism determines how the system allocates resources, which is a strategy serving the system objectives [8]. Different scheduling mechanisms should be designed for different systems and system objectives. In general operating systems, such as windows and Linux, the goal of scheduling mechanism or algorithm is to optimize the average performance of the system, such as average waiting time and throughput [9]. A variety of real-time scheduling methods have been proposed for different types of real-time systems, and a set of theoretical system has been established, and some application results have been achieved in practice [10-12].

At present, there are mainly two kinds of scheduling mechanisms for real-time systems: the first is the method of integrating multiple scheduling strategies based on servers in the hierarchical scheduling framework proposed by Z. Deng et al. [15-17]. It is a bandwidth reservation algorithm based on CUS(constant utilization server) and TBS (total bandwidth server), and builds a two-tier scheduling framework based on it. It emphasizes personalized task scheduling for application system, and adopts different system scheduling strategies for different constraints. At the same time, it adopts the receiving control strategy to ensure that the new tasks will not damage the schedulability of the system in the open environment. The second type is the unified architecture multi scheduling strategy fusion method proposed in [11]. The unified system scheduling model emphasizes multiple scheduling strategies and adopts a unified structure to realize the configuration of multiple scheduling strategies. However, there is only one scheduling strategy in the system, which emphasizes the flexibility of scheduling strategy configuration.

Papers [18,19] are devoted to the scheduling of soft real-time tasks, and propose a CBS (constant bandwidth server) method for scheduling tasks with determinable processor bandwidth. Each CBS serves the jobs generated by the tasks associated with it in FCFS (first come first served) order without exceeding its declared processor bandwidth.

The H-CBS (hierarchical CBS) algorithm proposed in reference [20] can further support bandwidth isolation between soft real-time task sets.

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In [21], two algorithms, EDL-RTO and EDL-BWP, are proposed to minimize the average response time of soft real-time aperiodic requests and ensure that the QoS of periodic tasks is no less than a specified value.

In [22], a non-preemptive gEDF (group Earliest Deadline First) algorithm is proposed for soft real-time multimedia application system, and experiments show that this algorithm is more effective in dealing with soft real-time multimedia applications.

The paper [23] is devoted to solving the scheduling problem of soft real-time system on multiprocessor platform, and points out that compared with applying EDF algorithm on each processor, applying gEDF (group Earliest Deadline First) algorithm on multiprocessor platform, will make the soft real-time tasks get higher processor utilization, improve the overall efficiency ofthe system, and when the system running time is long enough, the overall schedulability of soft real-time tasks can also be guaranteed.

PShED (Processor Sharing with Early Deadlines) algorithm proposed in [24] provides the independence between scheduling tasks. It allows real-time applications running at the same time in the system to use different scheduling methods, and the execution of ready jobs by its server is not limited to FCFS sequence. It only needs to know its deadline parameters, and then calculate theexecution budget of the server, but it can only be suitable for fully preemptive tasks.

The RPDS (Rigorously Proportional Dispatching Server) algorithm proposed in [25] establishes a new hierarchical scheduling framework. It schedules all kinds of tasks in time slices, but it does not consider the situation when real-time tasks use global resources or when there is no preemptive area in tasks, and it does not explain how the system accepts real-time tasks and non real-time tasks.

In [26], OARtS (Open Adaptive Real-Time Scheduling) scheduling framework is proposed, which introduces the idea of automatic control into the open real-time system scheduling, it can dynamically adjust the real-time level of tasks according to the situation of system resources, but it does not discuss some characteristic parameters of tasks, such as whether there is a non preemptivearea, whether to use global resources and so on, and needs a lot of calculation, which increases theburden of the system.

The paper [27] proposes a two-dimensional priority real-time scheduling mechanism, which divides the priority of scheduling algorithm and allocates the corresponding bandwidth. However, the bandwidth cannot be dynamically adjusted during the operation of the system, so it is difficult to make full use of the system resources.

5. EXISTING PROBLEMS, DEVELOPMENT TREND AND PROSPECT

With the increasing application of real-time system, the coexistence of multiple types of real-time and non real-time tasks brings new requirements and challenges to system scheduling methods. For example, in airborne radar real-time imaging system and other modern industrial control systems, including hard real-time tasks for controlling equipment and receiving data, and soft real-time tasks for video or audio processing.

In practical application, due to the changes of the system environment and the existence of a large number of emergencies, the types of tasks to be handled, the arrival time and the amount of computing resources required in the system are usually unpredictable, which can only be knownafter the task arrives. Obviously, in this kind of dynamic real-time system, on the one hand, it needs flexible scalability and dynamic configuration capability, while the closed real-time systemarchitecture and static real-time scheduling are no longer applicable. On the other hand, it needs thesupport of scheduling method with adaptive function to adapt to environmental changes at runtime.

At the same time, the expansion of the scale and complexity of the real-time system also make the development of the application more difficult. The original closed system structure is one of the main factors causing the long development cycle and poor scalability of the application system, so it does not meet the current development needs. The related research of open real-time system is concerned to solve these problems, and also brings new ideas for scheduling theory and method. Compared with the closed real-time system, the open real-time system has better compatibility and scalability, and reduces the difficulty of real-time verification in the development of real-time system. Adaptive real-time scheduling method is an important direction in the field of real-time system research, and the combination of feedback control technology and open real-time system is an inevitable trend caused by the actual demand. With adaptive scheduling function, the open real- time system can better adapt to environmental changes.

If the characteristics of the open real-time system that people imagine can be mature in both theory and implementation, it will bring great convenience to the design, development and maintenance of the real-time system, and solve some system functions (such as local scheduling, independent verification of real-time performance, etc.) that are difficult to realize in the closed real- time system.

Real time scheduling has always been a key problem in the research of real-time system, but the research and practice in this area is still very lacking. Therefore, it is suitable for the integrated scheduling framework and an adaptive scheduling method of open real-time system to solve

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some problems of scheduling theory and method that need to be improved. For example, to solve the problems of concurrent scheduling of multiple types of real-time and non real-time tasks, and to meet the scalability and dynamic configuration of the system; in addition, to make the open real- time system have adaptive scheduling ability, to explore a new adaptive real-time scheduling method.

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