Advanced Sheduling Policy and its Performance for the Embedded Real time System

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Abstract—Real time performance analysis is critical during the design and integration of embedded software to guarantee that application time constraints will be met at run time. To select an appropriate operating system for an embedded system for a specific application, OS services needs to be analyzed. These OS services are identified by parameters to form Performance Metrics. From five performance parameters of real-time operating system, scheduling latency and interrupt latency are the fundamental constraints for improving real-time performance of Linux OS. This paper analyzed the scheduling policyn in order to select right policy for the specific embedded application and also suggested the performance for advantage.

Keywords-operating system, real-time system, embedded system, Linux kernel, scheduling policy.

1. I. INTRODUCTION

Real-time systems are widely used in the construction of national defense, aerospace, industrial control and many other fields. As the most critical characters which may affect the whole system, real-time character is required to guarantee the performance of these systems. With the development of computer technology, electronic information technology, many systems are controlled by computer system currently. As the majority of general-purpose computers are using Microsoft's Windows or Linux which is open-source as operating system, which are not real- time operating system, so these systems have not enough real-time characters. At present, the vast majority of real-time systems are embedded systems while built through the embedded processors with embedded operating system. In this paper, "real-time systems" mentioned in the following text are embedded systems.

Combining both a real-time and a time-sharing subsystem, hybrid operating systems can provide both predictable real-time task execution and non real-time services with well known interfaces and lots of existing applications. In order ato achieve relatively low development and maintenance cost the time-sharing subsystem of a hybrid system is based on commodity operating system such as Linux[1]

ENERGY consumption is an important design concern for mobile embedded systems that are battery powered and thermally constrained. Displays have been known as one of the major power consumers in mobile systems . Conventional liquid crystal display (LCD) systems provide very little flexibility for power saving because the LCD panel consumes almost constant power regardless of the display content while the external lighting dominates the system power consumption [2]

Embedded system application is a hot topic in today's date & Linux gradually becomes the most important operating system for embedded applications. Embedded real-time system must be able to response and deal with system events within the pre-defined time limitation. In real-time multi-tasking system, a lot of events and multiple concurrent tasks are running at the same time. Therefore, to meet the system response time requirement, we must ensure that each mission can be achieved within the required time frame [8].

Real-time systems are specific application systems in general, because specific characteristics could ensure their real-time characters on a certain extent. Early real-time systems have no operating system supported. To implement multi-task management, engineers must program code for specific practical application. Therefore, these particular software developments are less inheritance for code reuse, maintenance and upgrades which brought a lot of trouble. The emergence of real-time embedded operating system provides a powerful tool for real-time systems design and development because of its real-time kernel, multi-task, scheduling and fast interrupt response mechanism and so on. Such real-time characteristics can significantly reduce the workload of developers, improve development efficiency, and bring a lot of convenience for the maintenance and upgrading systems.

However, a system that uses real-time operating is not necessarily a real-time system. Real-time operating system is just only provide a basis for the real-time system, and the most essential elements for a real-time system are to meet the system requirements of task-critical time, which means the system must response to events in time and complete tasks within the limited time[7].

2. II. REAL TIME OPERATING SYSTEM: ITS COMPONENTS AND CHARACTERISTICS

Real-time operating system is a subtype of operating system. It has a lot of characteristics which are similar to common operating system in many respects. It is mainly responsible for the control and management of variety of hardware resources to enable the hardware system to become available, and provides upper level applications with rich system calls. It schedules execution in a timely manner, manages system resources and provides a consistent foundation for developing application code [5].

A. Components of RTOS

Most of the RTOS kernels consist of following components:

- Scheduler - The scheduler is at the heart of every kernel. A scheduler provides the algorithms needed to determine which task executes when.
- Objects- The most common RTOS kernel objects are tasks, semaphores and message queues.
- Services- Most kernels provide services that help developers create applications for real time embedded systems. These services comprise sets of API calls that can be used to perform operations on kernel objects or can be used in general to facilitate following services:
  - Timer Management
  - Interrupt Handling
  - Device I/O
  - Memory Management

Embedded systems are used for various applications. These applications can be proactive or reactive dependent on the requirements like interface, scalability, connectivity etc. Choosing the OS for an embedded system is based on the analysis of OS itself and the requirements of application.

B. Characteristics

1. Its real time characteristic-Response to events in time and complete tasks within the limited time
1. The scheduling objective is letting high priority task go first
2. The tasks running on real-time operating system should be certain
3. Some data are highly sharing in real-time operating system

II. FACTORS AFFECTING REAL-TIME CHARACTERISTICS OF OPERATING SYSTEM

There are varieties of factors impacting a system's real-time. Among these factors, operating system and its own factors play crucial roles, including process management, task scheduling, context switching time, memory management mechanism, the time of interrupt handle, and so on.

A. Scheduling of tasks

It is crucial for the real-time operating system to adapt preemptive scheduling kernel, which is based on task priority. The μC/OS-II operating system uses this method to implement its scheduling. In an operating system with nonpreemptive scheduling mechanism, must have no strict real-time characteristic.

Preemptive scheduling provides a good foundation for real-time system. In order to maximize the efficiency of scheduling systems, the operating system should run with certain real-time scheduling algorithm.

There are some common real-time scheduling algorithms, such as the Liu and Layland Rate-Monotonic (RM) scheduling algorithm and the earliest deadline priority (EDF) algorithm. The RM scheduling algorithm is a type of static scheduling algorithm, in which the priority of tasks are determined by the length of the cycle of task, and the shorter cycle of task has a higher priority. The EDF algorithm is one of the most popular dynamic priority scheduling algorithms that define priority of tasks according to their deadlines. Clearly, an excellent task scheduling algorithm can improve the operating system's real-time characteristics. However, it also consumes a certain degree of system resources. Thus, time complexity of scheduling algorithm, in turn, has an impact on the real-time characteristic.

B. The context switching time

In a multi-tasking system, context switch refers to a series operation that the right of using CPU transferring from one task which is running to another ready for running one [6]. In preemptive scheduling systems, there are a lot of events that can cause context switches, such as external interrupt, or releasing of resource which high priority tasks wait for. The linkages of tasks in an operating system are achieved by the process control block (PCB) data structure. When context switches occurred, the former tasks information was saved to the corresponding PCB or stack PCB specified. The new task fetches original information from corresponding PCB. The time switching consumed depends on the processor architecture, because different processors need to preserve and restore different number of registers; some processors have a single special instruction which is able to achieve all the register's preserve and restore job; some processors provide a number of registers group, the context switching required only need to change the register group pointer [9]. Operating system data structures will also affect the efficiency of context switch.

C. The time of kernel prohibiting interrupt

To ensure the atomic of operating to some critical resource, the operating system kernel has to prohibit all of interrupt sometimes. Interrupt will break the sequence of instructions, and may cause damage of data. Prohibiting interrupt always delay the response of request and context switching. In order to improve real-time performance of operating system, noncritical operations can be inserted between the critical areas. Setting reasonable preemptive points in critical areas can reduce the prohibition time of interrupt.

D. *Efficiency and treatment methods of interrupt*

As the driving force for operating system scheduling, interrupt provides approaches of interaction between external events and operating system. The interrupt response speed is one of the most important ingredients which impact the real-time performance of system. At the end of each instruction execution, CPU will detect the status of interrupt. If there is an interrupt request and the interrupt is not prohibited, the system will execute a series of interrupt treatments: pushing values of CPU registers to stacks, obtaining the interrupt vector and getting the procedures counter register value, then jumping to the entrance of ISR and beginning to run, etc. [3]. What have mentioned above requires some system consumption. For a specific system, the consumption is identifiable, that is to say: it is possible to calculate the time delay of interrupt treatment caused by this part of work.

As interrupt management strategy, allowing interrupt nesting can further improve the response of high-priority incident's real-time, but relatively low-priority interrupt handling will be suffer negative impact. It should be considered under certain situation.

Non-emergency interruption may cause delay to important and urgent tasks, because interrupt handling is executed before task and thread. In order to reduce the delay, the handle process should be divided into two parts, just like Linux divided it into the top half and bottom half. Also Windows CE's interrupt handling is divided into two parts: ISR and IST. They tried to keep ISR as a short program, while allowing tasks do more work, and make full use of the task scheduling mechanism.

E. *Memory management mechanism*

Generally, a real-time operating system uses the most efficient unified physical address space. Every task runs in the same address space. This management method can avoid the address space switching caused by the process scheduling that will occupy a lot of system resources. Because converting virtual address to physical address will lower the system performance, real-time operating systems use physical address directly, although it may bring security and stability problems. One of the most popular embedded operating systems-Vxworks uses the mechanism.

Real-time operating systems never use virtual memory, because it is hard to estimate the time of fetching data from external storage medium. When a page miss occurs, memory management should swap pages between internal memory and external memory. This process will suspend current running task. So the execution of real-time task cannot be assured.

F. *The race condition among tasks*

The tasks of the system may compete for sharing resources. It will definitely cause some tasks to suspend and wait for the sharing resource. In preemptive scheduling kernel, priority inversion is a serious problem caused by race condition. A low-priority task which occupies critical resources has no right to implement, while a high-priority task has to wait a middle-priority task to release CPU to low-priority task. So the high-priority task is affected seriously and the task scheduling will become unstable and unpredictable. The real-time performance of system deteriorates rapidly. After all, the high-priority task can only seize the CPU from the low-priority task. It can't seize the resources. At this condition, it is necessary to use priority inheritance and priority ceiling to resolve the problem.

III. ANALYSIS OF LINUX KERNEL'S REAL TIME PERFORMANCE AND HOW IT IS RESTRICTED

It's well known that an operating system's real-time performance is evaluated by the following five technologic parameters: Deterministic, Preemptive, Context Switching, Interrupt Latency and Scheduling Latency [1, 2]. Context Switching is relative with specific CPU and Deterministic is determined by the remaining three aspects. So in this paper Linux kernel's real-time performance is discussed from Preemptive, Interrupt Latency and Scheduling Latency.

A. *Preemptive*

In general there are two modes in Linux kernel which are user state and core state. When a process operates at user state, preemptive scheduling is possible to happen if there is no shared data. But at core state the kernel is non-preemptive [4] and the tasks ready to run must be done in sequence. When a critical section of code is executed or Preempt disable command is used, the task cannot be preempted. In other words Linux kernel's preemptive performance still doesn't meet the need of hard real-time performance.

B. *Scheduling Policy*

Scheduling latency is the time that it takes for a high priority task ready to run caused by an event to wait to be done and is determined by interrupt latency, non-preemptive time and scheduling algorithm. In general Linux kernel scheduling algorithm is an O(n) algorithm indicating scheduling time is relative with the task scale, which is caused by concentrated computing time slices. Scheduling time is certain independent of task scale because Active queue and Expired queue are set so that it is unnecessary to compute time slices concentrated and scan the whole queue before scheduling switch. Thus easily resulting in that non-real-time task blocks real-time one by disabling interrupt.

C. *Interrupt Latency*

An interrupt has the highest priority and can preempt any task. It is common to disable interrupt for safety in Linux kernel process. If lower priority tasks disable interrupt there will be uncertain latency time for real-time task's response, which is not allowed for real-time system.

D. Improvement on Linux Kernel Real-Time performance

It takes long time for Linux kernel to develop and its performance to increase. However for the standard Linux kernel its real-time performance is always a problem unable to be solved completely. It is not because the designers are not excellent for many top programmers and engineers in the world take part in developing Linux kernel, but the standard Linux kernel needs to take into account fairness, balance and scale compatibility, and many other factors so that real-time performance has to give in. The real-time performance of Linux kernel is improved by improving both scheduling strategy and interrupt latency which block real-time task.

IV. SCHEDULING POLICY AND THEIR PERFORMANCE

Comparision of Scheduling policies for embedded system which is to be executing the real time system. We have executed two policies like shorter service time first and longer service time first. These policies are then compared with the First In First Out policy which is very common. The camparision also gives us better understanding of how a scheduling policy can influence the execution of Real time systems performance.

Following table1 shows the details for FIFO.

Time	10	20	30	40
Average wait time	0.7631	2.764	3.973	3.518
Average Queue Length	0.9224	3.467	4.041	3.537

Following table2 shows the details for Shorter Service Time First.

Time	10	20	30	40
Average wait time	0.6093	1.395	2.152	2.016
Average Queue Length	0.9768	2.306	2.299	2.027

Following table3 shows the details for Longer Service Time First.

Time	10	20	30	40
Average wait time	1.073	2.174	4.715	4.761
Average Queue Length	1.192	4.44	5.912	6.408

From the above observations it is very clear that the Shorter seek time first policy yields the better results.

V. CONCUSION

The selection of right operating system for a specific application has a great impact on performance of real- time system. In the embedded application the improvement of real-time performance of Linux kernel has far-reaching significance. The complex relationship between the tasks may cause heavy system consumption on internal communication between tasks. The Scheduling and separating the tasks in the beginning will also give us flexibility to apply different algorithms for different task queues. Synchronization mechanism between tasks will decline the real-time performance of system. At last, which scheduling algorithm to use a real-time operating system to implement an actual application system is the key for all embedded system developer.

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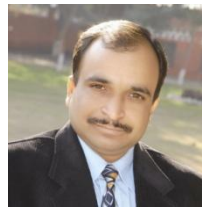
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