

Real-Time & Linux

Sources:

“Real-time Systems” by (Jane Liu, 2000) Ch 2

”HOWTO build a simple RT application” by the Linux Foundation

https://wiki.linuxfoundation.org/realtime/documentation/howto/applications/application_base

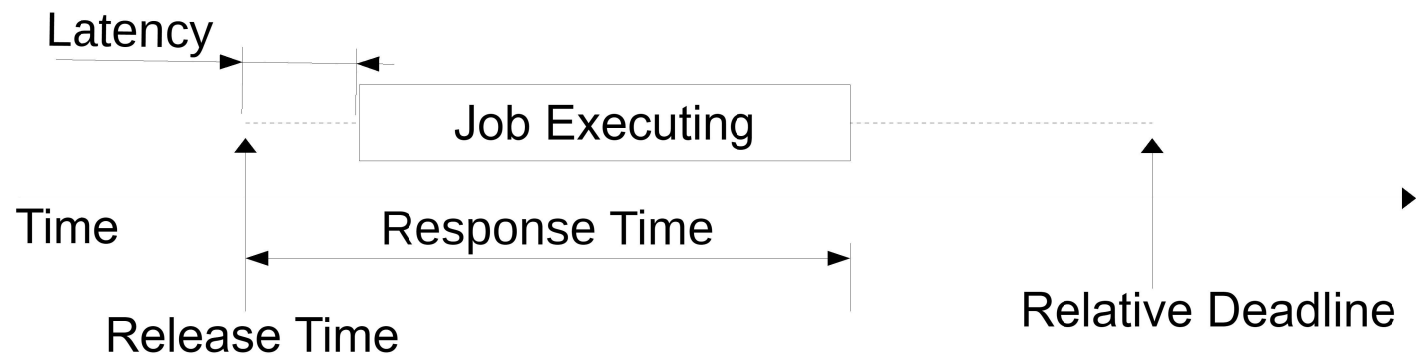
Topics

- 1) What is Hard vs Soft real-time?
- 2) How can we know when a task will run?
(Deterministic Latency)

Hard vs Soft Real-Time

Timing Constraints

- Job
 - ..
 - Example: calculating the statistics over hundreds of light-intensity samples each second.
- Real-Time (RT) systems have jobs that must be started and completed by certain times.



- Job's timing constraint: its release time and relative deadline

Common Definitions

- Common definitions
 - Hard RT
missing a timing deadline is considered a fatal flaw in the system.
 - Ex: collision avoidance system on a train yields a crash.
 - Soft RT
missing a timing deadline yields degraded performance.
 - Ex: video playback yields a stutter
- Poor definition because it's subjective:
it depends on defining how fatal "late" is.

Our Definitions of RT

- Hard Realtime
 - User requires..
 - "Guaranteed Services"
Mathematical/logical proof or exhaustive simulation required
 - Hard real-time is about..
- Soft Realtime
 - User only requires..

(statistical analysis)
 - "Best effort Services"
Ex: Average # missed deadline < 2 per minute.
 - Soft real-time is about..

Goals of RT

- What is latency?
 - Latency is..
 - We often care about critical tasks such as responding to high-priority interrupts (interrupt latency)
- Goal
 - low and deterministic latency
- Example:
 - Battery Management System:
over-current detection triggers bank shutdown
 - Effect of non-deterministic latency in this example
 - [Draw a picture]

Hard RT: Scheduling Guarantees

- Example
 - Airplane flight control needs reliable timing to:
 - Read sensors
 - Compute “control-laws” to generate responses
 - Send responses to actuators
- OS guarantees
 - ..
- How?
 - Each new job comes with a duration and a deadline
 - System only allows new job if it can guarantee it can complete it by the deadline

Deterministic Latency

Deterministic Latency

Deterministic low latency RT requires:

- ..
 - support low-latency response
 - requires preemptible kernel with short critical sections
- ..
 - Avoid non-deterministic latencies on RT path
 - Use OS features for memory & scheduling

OS: Linux RT Patch

- Linux RT patch: PREEMPT_RT
 - Goal is to "minimize the amount of kernel code that is non-preemptible." (<https://lwn.net/Articles/146861/>)
- Patch has been cleaning up Linux kernel for years
 - Many of its features are on the "mainline" and have improved Linux for general uses (ex: better audio)
 - RT Patch makes kernel interruptible almost everywhere
- [DRAW]: syscall & context switch process
 - 1) App executes sys-call
 - 2) Kernel provides services; returns to app

Any time: Kernel timer invokes context switch

Application Req for Deterministic Latency

- Step 1:
 - OS supports low latency
(just saw that!)
- Step 2:
 - RT application takes steps to prevent nondeterministic latencies
 - Example sources of non-deterministic delays
 - memory faults
 - scheduling delays and context switches
 - priority inversion (later)

App 1) Memory Locking

- Swap Memory
 - A computer's memory (RAM) is divided up into pages. When running low on memory, OS swaps pages out to disk (swap file).
 - Even without swap file, OS can "swap" our executable code's memory page because it's already on disk.
- Page fault
 - If page is swapped to disk,...
- Problem
 - Page faults are..

App 1) Memory Locking solution

- Solution: Memory Locking
 - Ask the kernel to

..

```
/* Lock all current and future pages
   preventing being paged to swap */
if (mlockall( MCL_CURRENT | MCL_FUTURE )) {
    perror("mlockall failed");
    exit(-1); // Or handle error
}
```

- Run this code before any RT processing starts

App 2) Stack Memory

- Each thread has its own stack in memory.
 - If spawning many threads, can..
- Problem
 - If all pages are locked in RAM, we must ensure we don't exhaust available memory.
 - Spawning new thread allocates new memory; if locked to RAM then triggers a page fault.
- Solution
 - ..
 - Understand memory use of each thread, and..
(default ~8mb)

App 2) Stack Memory

- Set thread stack size:

```
static void create_rt_thread(void)
{
    pthread_t thread;
    pthread_attr_t attr;

    /* init to default values */
    if (pthread_attr_init(&attr))
        error(1);

    /* Set a specific stack size */
    int size = PTHREAD_STACK_MIN + MY_STACK_SIZE;
    if (pthread_attr_setstacksize(&attr, size))
        error(2);

    /* Finally start the actual thread */
    pthread_create(&thread, &attr, rt_func, NULL);
}
```

App 3) Dynamic Memory

- Problem
 - Dynamically allocating or freeing memory can ..
- Solution
 - RT critical paths should not dynamically allocate or free memory.
 - Instead, preallocate all memory for RT paths:
 - init() functions dynamically allocate memory
 - Non-RT code allocate memory, pass pointer to RT path
 - ..

App 4) Priorities and Scheduling

- OS schedules tasks (jobs) based on its scheduling algorithm and task priority.
- Problem
 - Some tasks are more time critical, and must be run sooner than others.
- Solution
 - Assign each task a reasonable priority
 - ..
- More to come on this!

Summary

- Real-time
 - Hard RT requires scheduling guarantees
 - Soft RT requires a best-effort with low latency
- OS Features
 - Preemptable kernel with priorities for tasks
- App Features
 - Memory locking to prevent page faults
 - Task stack memory management to reduce memory pressure
 - No dynamic memory allocation/free on RT path
 - Task priorities