Real-Time in the Real World

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From Theory...

- Real-time system: $\{\tau_i\}$
  - $\tau_i : (C_i, T_i)$
  - Independent tasks
  - Periodic tasks, $D_i = T_i$
  - WCET???
- Theoretical schedule: function $t \rightarrow \tau_i$
- 1 CPU

...To Practice

- Real-time system: $\{\tau_i\}$, $\{S_k\}$
- $\tau_i : (C_i, D_i, T_i)$
- Sporadic Tasks
  - Minimum Inter-Arrival Time???
- Still do be solved:
  - Do something about WCET and MIT knowledge
  - Scheduling for more than 1 CPU (example: SMP or multicore)
  - Take OS overhead (and practical issues) into account

The WCET

- Schedulability analysis is based on the WCET
- But... How can I know it?
  - Today, my crystal ball is broken...
- Problem: a task τ_i executing for more than C_i can cause deadline misses in a different task τ_j
- Two possible solutions:
  - Analyse the effects of variations in the WCETs: Sensistivity Analysis
  - Limit the execution time in some way (enforcing a WCET): Resource Reservations

Sensitivity Analysis

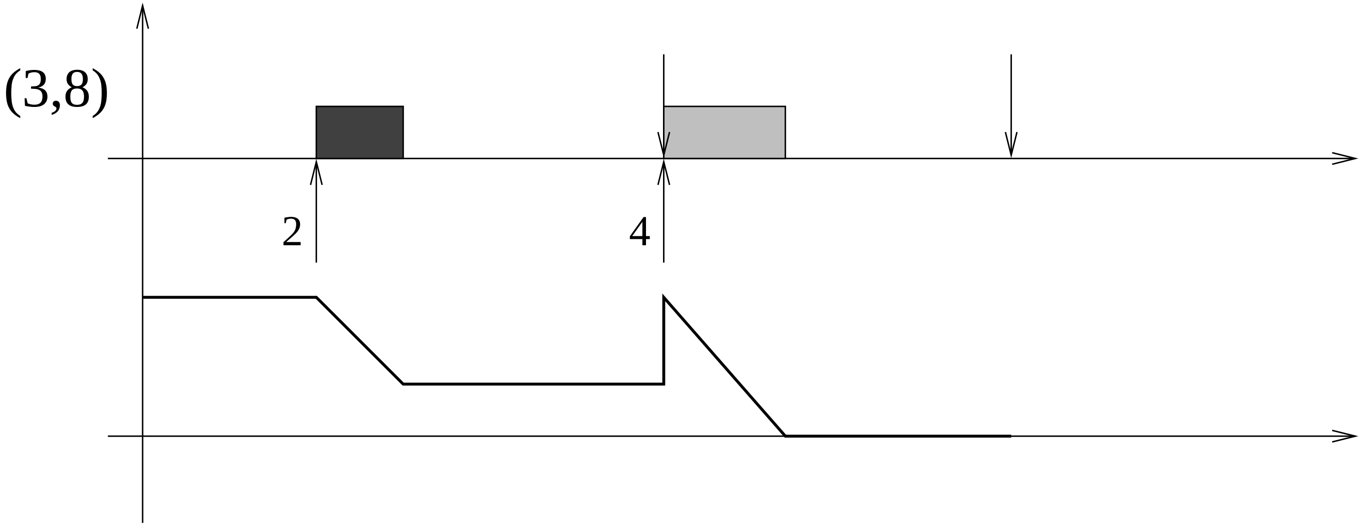
- WCETs are estimations. What happens if my WCET estimation is wrong?
  - A job $J_{i,j}$ can execute for a time $c_{i,j} > C_i$!
- What's the acceptable error in WCETs estimations?
- Formulate TDA or RTA as a sensitivity analysis problem
  - How sensible is the demanded time (or response time) to variations of the WCETs?
  - Example: What happens to R_i if C_h (with $p_h > p_i$) is increased by a small amount δ?
  - $R_i = f(C_1, \ldots C_i, T_1, \ldots T_{i-1})$; $f()$ is not linear...
- Complex analysis, not explained here (see old slides if you are curious)

Reservation-Based Scheduling

- Force the task not to demand more time than a periodic (or sporadic!) (Q, T) task
- How to enforce this?
  - Measure the demanded time, and deschedule the task when it's too much
  - Similar to "traffic shaping used in networks"
- Temporal Protection!!!
  - If task τ_i executes for more than $Q_i = C_i$, it will be blocked...
  - ...τ_i will miss a deadline (not other tasks!!!)
  - Similar to memory protection...

Implementing Temporal Protection

- Budget q, consumed when the task executes
  - When the budget is 0 the task cannot be scheduled
- Budget
  - Accounting (Enforcement)
  - Replenishment



Aperiodic Servers

- How to cope with the MIT?
  - Aperiodic tasks: no particular structure (no knowledge about the MIT)
- Traditional solution: use a periodic (or sporadic) task to serve aperiodic requests...
- Aperiodic Servers
  - Polling Server, Deferrable Server, Sporadic Server, ...
- Implementation: use a budget...
  - We end up with resource reservations, again!!!

Multiprocessor Scheduling

- Real-Time scheduling with more than 1 processor?
- Trivial solution: partitioned scheduling
  - Statically assign tasks to CPUs
  - Reduce the problem of scheduling on M CPUs to M instances of uniprocessor scheduling
  - Problem: system underutilisation
- Global scheduling
  - One single ready task queue
  - Select the first M tasks from the queue
  - Problem: migrations...