Real-time Scheduling

Tanenbaum
Section 2.5, Section 7.4.2-7.4.4
Real Time Scheduling

• Correctness of the system may depend not only on the logical result of the computation but also on the time when these results are produced, e.g.
  – Tasks attempt to control events or to react to events that take place in the outside world
  – These external events occur in real time and processing must be able to keep up
  – Processing must happen in a timely fashion, neither too late, nor too early
Real Time System (RTS)

- RTS accepts an activity $A$ and guarantees its requested (timely) behaviour $B$ if and only if
  - RTS finds a schedule
    - that includes all already accepted activities $A_i$ and the new activity $A$,
    - that guarantees all requested timely behaviour $B_i$ and $B$, and
    - that can be enforced by the RTS.
  - Otherwise, RT system rejects the new activity $A$. 

THE UNIVERSITY OF NEW SOUTH WALES
Typical Real Time Systems

- Control of laboratory experiments
- Robotics
- (Air) Traffic control
- Controlling Cars / Trains / Planes
- Telecommunications
- Medical support (Remote Surgery, Emergency room)
- Multi-Media

• Remark: Some applications may have only **soft-real time** requirements, but some have really **hard real-time** requirements
Hard-Real Time Systems

• Requirements:
  – Must always meet all deadlines (time guarantees)
  – You have to guarantee that in any situation these applications are done in time, otherwise dangerous things may happen

Examples:
  1. If the landing of a fly-by-wire jet cannot react to sudden side-winds within some milliseconds, an accident might occur.
  2. An airbag system or the ABS has to react within milliseconds
Soft-Real Time Systems

Requirements:

Must *mostly* meet all deadlines, e.g. 99.9% of cases

Examples:

1. Multi-media: 100 frames per day might be dropped (late)
2. Car navigation: 5 late announcements per week are acceptable
3. Washing machine: washing 10 sec over time might occur once in 10 runs, 50 sec once in 100 runs.
Properties of Real-Time Tasks

- To schedule a real time task, its properties must be known \textit{a priori}.
- The most relevant properties are:
  - Arrival time (or release time) $a_i$
  - Maximum execution time (service time) $s_i$
  - Deadline $d_i$
Categories of Real time tasks

• Periodic
  – Each task is repeated at a regular interval
  – Max execution time is the same each period
  – Arrival time is usually the start of the period
  – Deadline is usually the end

• Aperiodic (sporadic)
  – Each task can arrive at any time
Real-time scheduling approaches

• **Static table-driven scheduling**
  – Given a set of tasks and their properties, a schedule (table) is precomputed offline.
    • Used for periodic task set
    • Requires entire schedule to be recomputed if we need to change the task set

• **Static priority-driven scheduling**
  – Given a set of tasks and their properties, each task is assigned a fixed priority
  – A preemptive priority-driven scheduler used in conjunction with the assigned priorities
    • Used for periodic task sets
Real-time scheduling approaches

• Dynamic scheduling
  – Task arrives prior to execution
  – The scheduler determines whether the new task can be admitted
    • Can all other admitted tasks and the new task meet their deadlines?
      – If no, reject the new task
  – Can handle both periodic and aperiodic tasks
Scheduling in Real-Time Systems

• We will only consider periodic systems

Scheduled real-time system

• Given
  – \( m \) periodic events
  – event \( i \) occurs within period \( P_i \) and requires \( C_i \) seconds

• Then the load can only be handled if

\[
\sum_{i=1}^{m} \frac{C_i}{P_i} \leq 1
\]
Two Typical Real-time Scheduling Algorithms

• Rate Monotonic Scheduling
  – Static Priority priority-driven scheduling
  – Priorities are assigned based on the period of each task
    • The shorter the period, the higher the priority

• Earliest Deadline First Scheduling
  – The task with the earliest deadline is chosen next
A Scheduling Example

- Three periodic Tasks

Starting moment for A1, B1, C1
Deadline for A1
Deadline for B1
Deadline for C1

Time (msec)
Is the Example Schedulable

\[ \sum_{i=1}^{m} \frac{C_i}{P_i} \leq 1 \]

\[ \frac{10}{30} + \frac{15}{40} + \frac{5}{50} = 0.808 \]

• YES
Two Schedules: RMS and EDF
Let’s Modify the Example Slightly

- Increase A’s CPU requirement to 15 msec
- The system is still schedulable

\[
\frac{15}{30} + \frac{15}{40} + \frac{5}{50} = 0.975
\]
RMS and EDF
RMS failed, why?

• It has been proven that RMS is only guaranteed to work if the CPU utilisation is not too high
  – For three tasks, CPU utilisation must be less than 0.780
• We were lucky with our original example

\[ \sum_{i=1}^{m} \frac{C_i}{P_i} \leq m(2^{1/m} - 1) \]
EDF

- EDF always works for any schedulable set of tasks, i.e. up to 100% CPU utilisation

- Summary
  - If CPU utilisation is low
    - Can use RMS which is simple and easy to implement
  - If CPU utilisation is high
    - Must use EDF