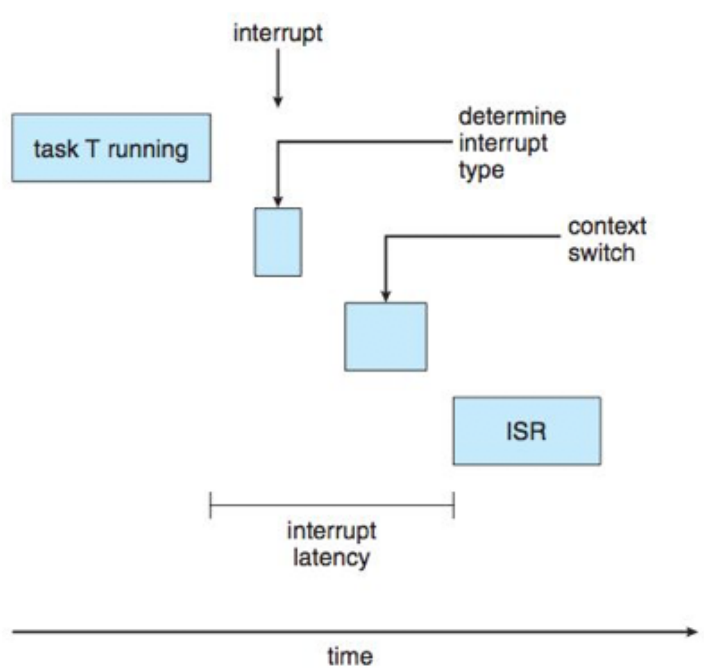
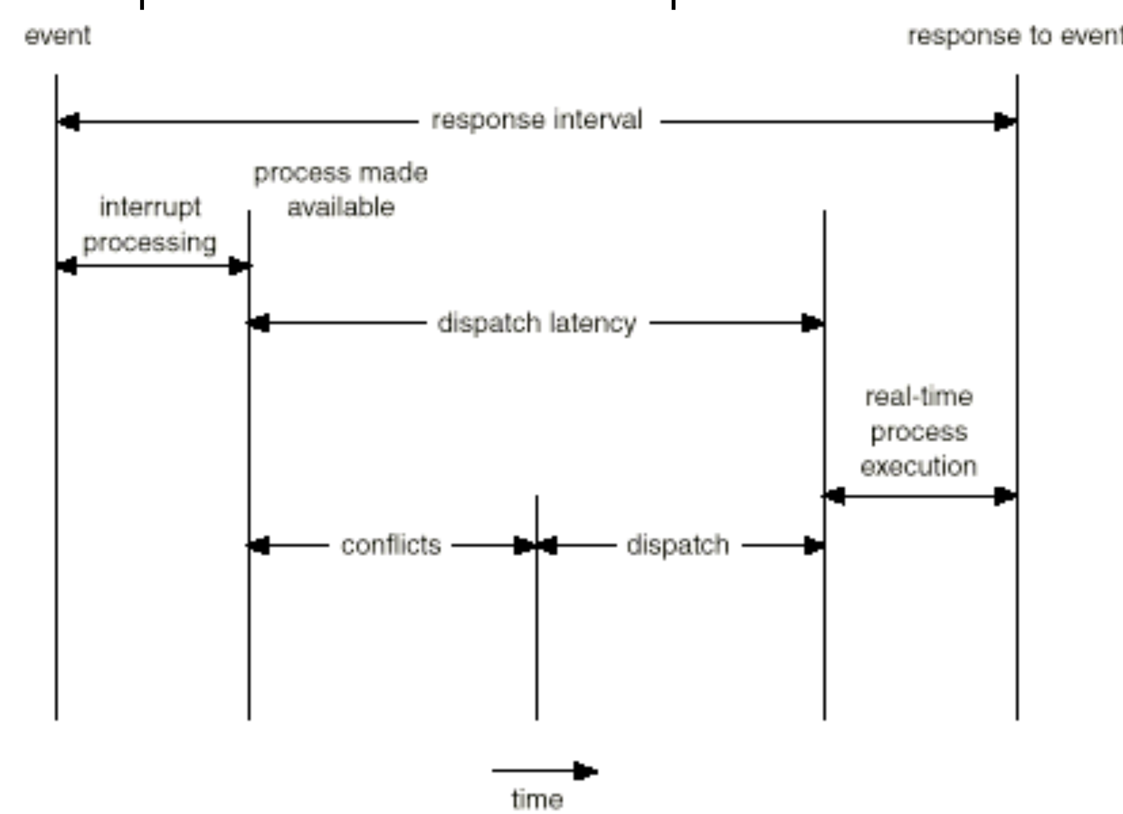
Real-time Scheduling

- *Hard real-time* systems – required to complete a critical task within a guaranteed amount of time.
- *Soft real-time* computing – requires that critical processes receive priority over less *important* ones.
- When processes are submitted they indicate their CPU requirements.
- The scheduler may reject the process if the requirement cannot be met.
- But very important processes can force other processes to relinquish their allocations.

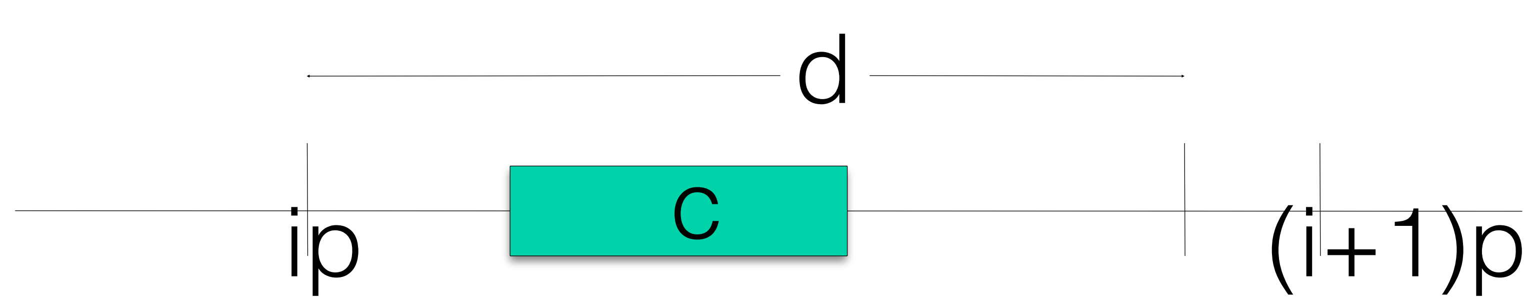




Real-time scheduling

Periodic and Sporadic processes

- Periodic
  - activate regularly between fixed time intervals
  - used for polling, monitoring and sampling
  - predetermined amount of work every period
- Sporadic
  - event driven – some external signal or change
  - used for fault detection, change of operating modes
- (c, p, d)
  - c – computation time (worst case)
  - p – period time
  - d – deadline
  - c <= d <= p



Periodic processes

- Period and Deadline are determined by the system requirements (often the same).
- Computation time is found through analysis, measurement or simulation.
- When the computation is complete the process is blocked until the next period starts.
- Sometimes it doesn’t matter if the deadline extends beyond the period or the period can change depending on system load.

Sporadic processes

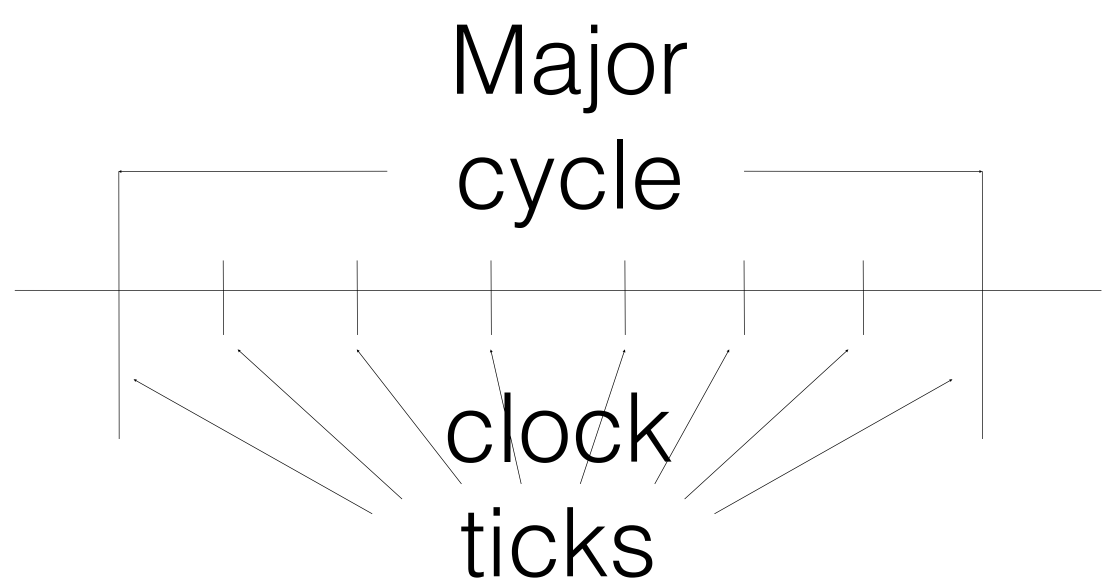
- (c, p, d) still applies
  - c and d have the obvious meaning
  - p is the minimum time between events
- aperiodic processes
  - p = 0
  - events can happen at any time, even simultaneously
  - timing can no longer be deterministic but there are ways of handling this
    - statistical methods, we design to satisfy average response times
    - if it is rare that the system has timing faults then special cases can be included in the handling code

Cyclic executives (CEs)

- Handles periodic processes.
- Sporadic processes can be converted into equivalent periodic processes or they can be ignored (if they take only a little time to handle).
- Pre-scheduled – a feasible execution schedule is calculated before run time.
- The cyclic executive carries out this schedule.
- It is periodic.
- Highly predictable – non-preemptible
- Inflexible, difficult to maintain.

CE schedule

- Major schedule – cyclic allocation of processor blocks which satisfies all deadlines and periods.
- Minor cycle (or frame) – major schedules are divided into equal size frames. Clock ticks only occur on the frame boundaries.



CE example

- Periodic processes:
- A = (1, 10, 10), B = (3, 10, 10), C = (2, 20, 20) D = (8, 20, 20)
- Major cycle time is 20 (smallest possible value we can use in this case). LCM of periods.
- Frame time – can be 10, GCD of periods.
- A feasible schedule:

idle

A	B	B	B	C	C	D	D	D	D	D	D	D	D	A	B	B	B		

Scheduling with priorities

- Scheduling decisions are made:
  - when a process becomes ready
  - when a process completes its execution
  - when there is an interrupt
- Priorities can cause schedules to not be feasible.

  A = (1, 2, 2) better priority

  B = (2, 5, 5) worse priority
- This is feasible (without preemption), but if the priorities are reversed it is not.
- Still priorities are almost always used
  - fixed – determined before execution
  - dynamic – change during execution

Priority allocation

Fixed

- Rate monotonic (RM) – the shorter the period the higher the priority.
- Least compute time (LCT) – the shorter the execution time the higher the priority (shortest job first)

Dynamic

- Shortest completion time (SCT) – shortest job first with preemption. But this time we have *good* information on the execution time requirement.
- Earliest deadline first (EDF) – the process with the closest deadline has the highest priority.
- Least slack time (LST) – the process with the least slack time has the highest priority.
  - Slack time is the amount of time to the process's deadline minus the amount of time the process still needs to complete.

Calculating schedules

- Calculate a schedule for the following two processes using EDF and SCT.

  A = (2, 4, 4) B = (5, 10, 10)

- EDF

A	B	A	B	A	B	A	B	A

0 2 4 6 9 11 12 14 18 20

- SCT
  - Same as above
- What about LST?
  - Same as above until time 17.

Theory

- For static priorities
  - RM is an optimal scheduling policy
  - If the CPU usage is < ln2 ≈ 0.69 RM will always find a schedule.
- For dynamic priorities
  - EDF and LST are optimal
- But these are only true for single processors.

"The most practical policy for multiprocessors is to pre-assign processes to CPUs using some heuristic, and then to schedule each one independently."

- Also theory assumes complete knowledge – non-preemptible resources, precedence constraints, interrupt and context switching times all need to be taken into account (see the diagrams on slide 1).

Before next time

- Read from the textbook

  5.1 Background

  5.2 Critical-Section Problem

  5.3 Peterson's Solution

  5.4 Synchronization Hardware

  5.5 Mutex Locks

  5.6 Semaphores

  5.7.1 The Bounded-Buffer Problem