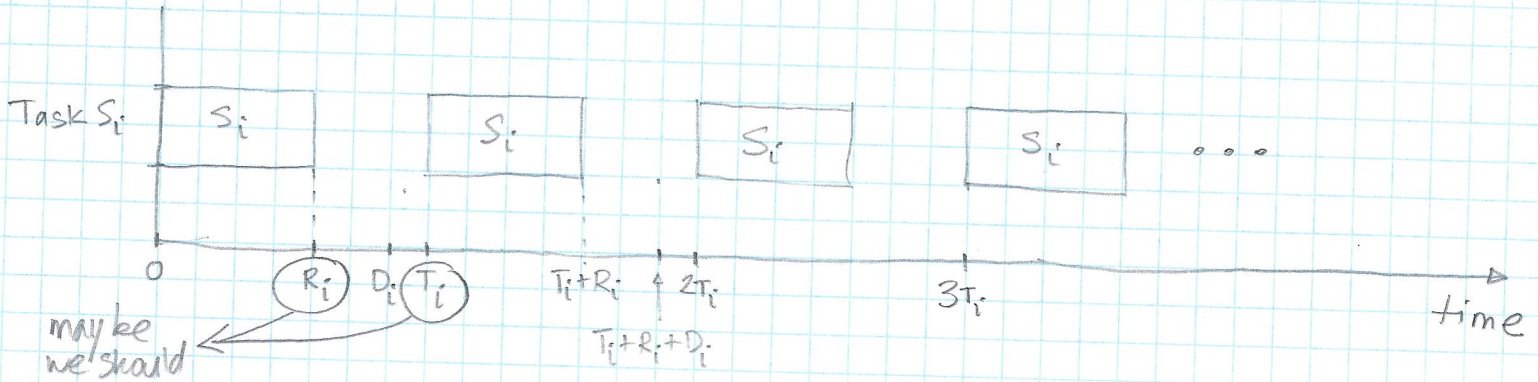
MORE MULTI-TASKING

- as we have seen, the conventional Linux kernel is not strict in the sense of task timing; Linux is designed as a "time sharing" system that attempts to provide CPU time for all users, rather than prioritize any given process.
- in a real-time OS, the scheduler is designed to be task-deadline driven, prioritizing certain tasks over others.
- hard real-time systems have time constraints which are absolute; that is, a total system failure may result from a single missed deadline. Examples of hard real-time systems include signal processing devices with fixed sampling periods, high-performance autonomous control systems found in robotics, cars and aircraft — if strict timing is not maintained, the consequences can be severe.
- soft real-time systems are those for which strict timing is desirable but for which an occasional missed deadline has insignificant or mild consequences.
- in truth, it is difficult in many cases to prove that a system will never miss a deadline — reality presents situations that the designer may not have anticipated
- to help us to estimate the "real-time robustness" of an OS, we often assume certain conditions that simplify things in order to perform analysis. For example, we might assume deterministic (predictable) conditions, which preclude unexpected events. Tasks may be assumed to have fixed execution times and periods:

useful terminology follows...

- Suppose we have a number of tasks, each denoted by S_i, $i = 1, \ldots, N$, each with a corresponding deadline (D_i), release time (R_i), and task period (T_i).

On a timeline, we could represent the task as:



maybe we should not distinguish between these two

- the deadline, D_i, is the amount of time the task S_i has to execute;
- the release time R_i is the time taken by the task, from when it first becomes active, until completion

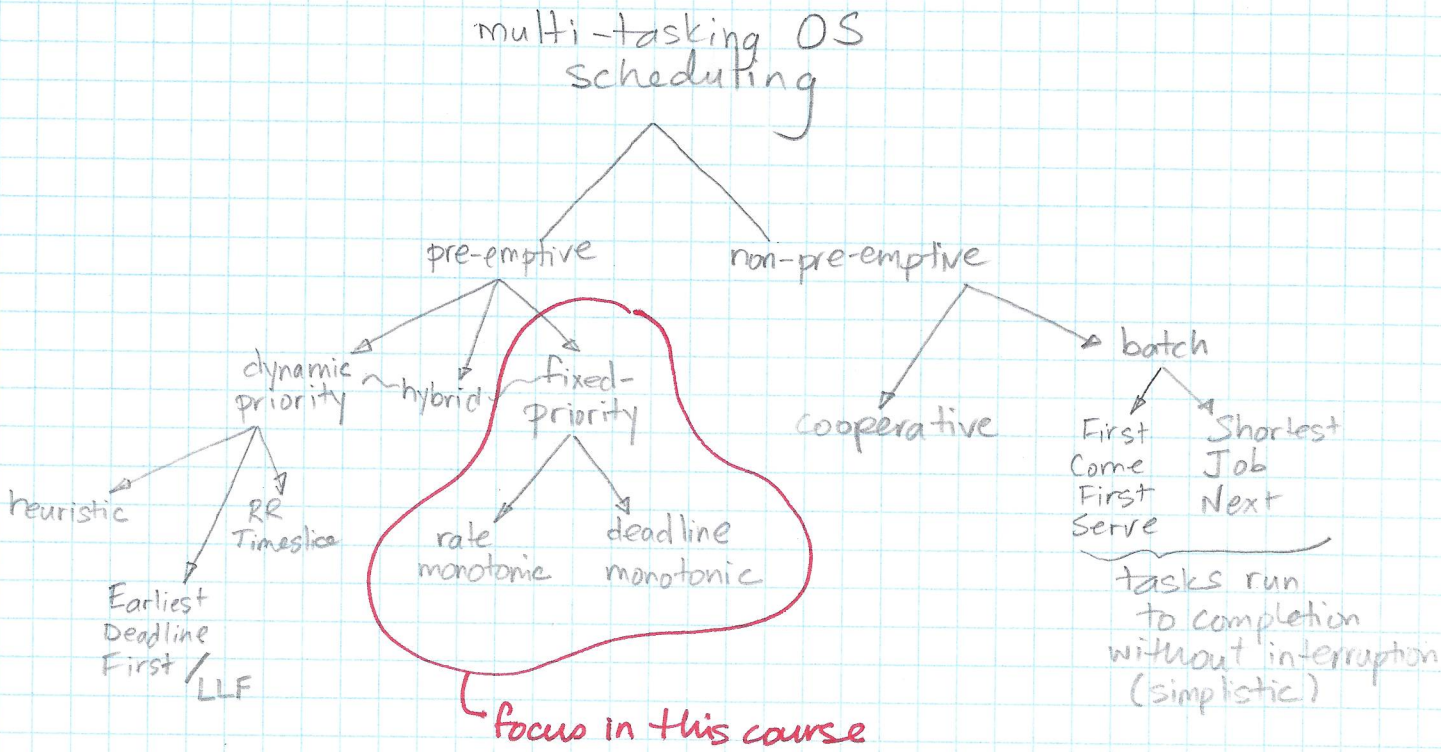
IT IS BEST TO THINK OF RELEASE PERIOD AS T_i

NOTE: in many examples, we often see that $D_i = R_i = T_i$ is used as a simplifying condition

- T_i is the task period — it is sometimes helpful to assume a fixed amount of time between executions of a task although in many real-world cases some deviation from periodic behaviour should be anticipated.

- Please bear in mind that:
  - real-time systems are often analyzed with deterministic assumptions (i.e., events are predictable);
  - service/task requests are periodic, and execution times of tasks are fixed (and known)
  - designers attempt to prove optimality (see below)

taxonomy of multi-tasking operating systems:



- fixed-priority design is at the foundation of pre-emptive operating systems
- Rate Monotonic (RM) and Deadline Monotonic (DM) two assignment policies in the fixed-priority category; both are optimal.
- An assignment policy is optimal if any set of services that can be scheduled with no missed deadlines can be scheduled with the assignment policy

→ optimality is a theoretical guarantee that a system is a hard real-time system ←

→ but bear in mind that many assumptions are made (described above) in any proof of optimality.

- in a **rate monotonic** (RM) policy, higher priority is given to tasks with the highest request frequency (shortest task period) J_i

- in a **deadline monotonic** (DM) policy, higher priority is given to tasks with the shortest deadline;

- note that if $D_i = R_i = T_i$, RM and DM are equivalent.

EXAMPLE:

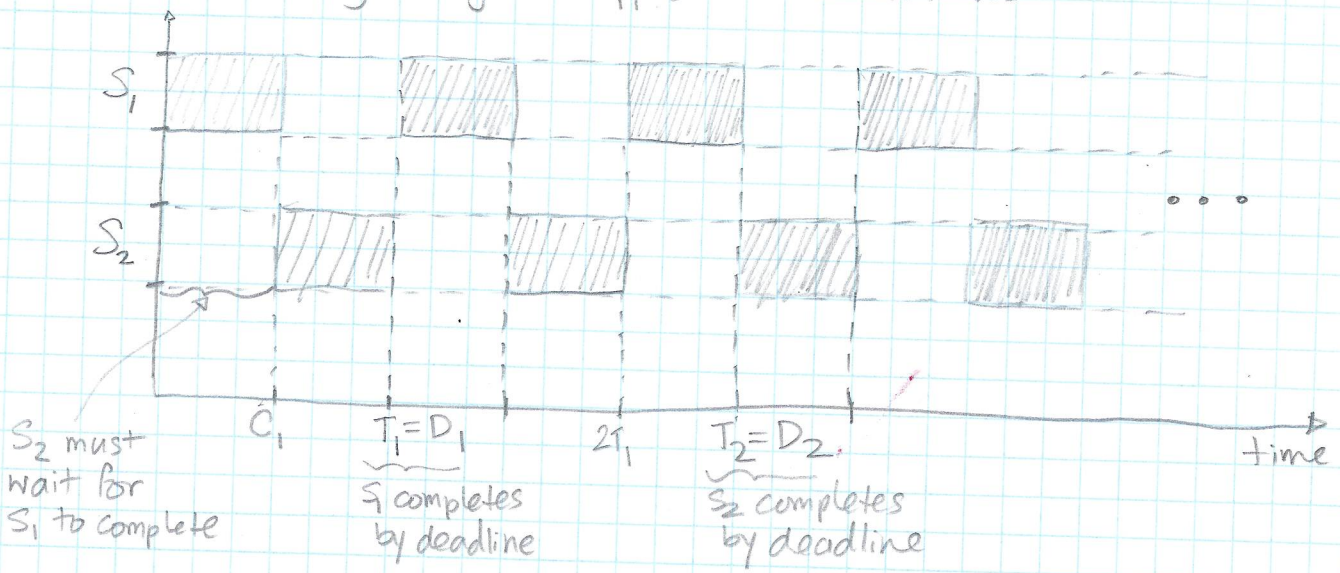
- given two tasks S_1 and S_2 with request periods $T_1 = 6$ and $T_2 = 15$ (in some unit of time), and execution times $C_1 = 3$ and $C_2 = 6$ (same time units), respectively, how does RM policy apply?

SOLN:

- because RM policy assigns higher priority to shorter task periods, we have that

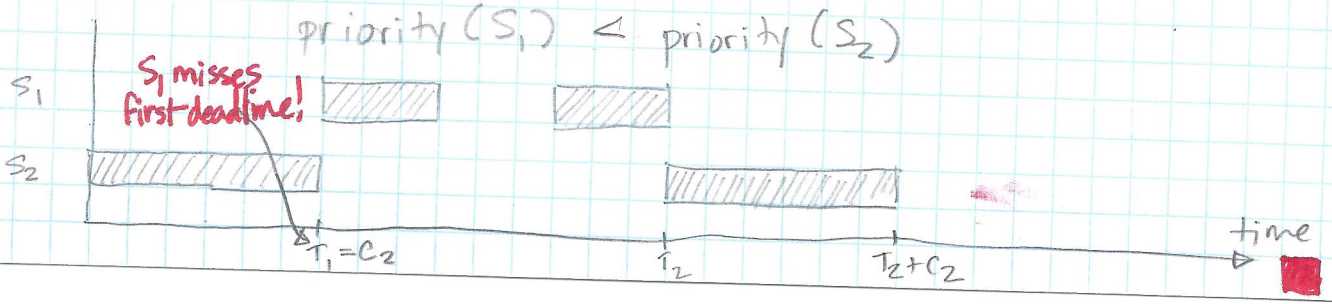
priority(S_1) > priority S_2

a timing diagram appears as follows:



- if we adopt the anti-policy, i.e.,

priority(S_1) < priority(S_2)



- in dynamic-priority RTOS, priority assignments are adjusted as tasks are released — think of it as a continuous adjustement
- please note that the terms "release period" and "request period" are used interchangeably in the text and some confusion might be created; we will use the symbol T_i to denote the release or request period from now on.
- also note that we will use the parameters T_i and C_i to characterize a task or service S_i, where C_i is the task execution time.
- here is an example comparing RM and EDF policies — recall that EDF is a dynamic method.

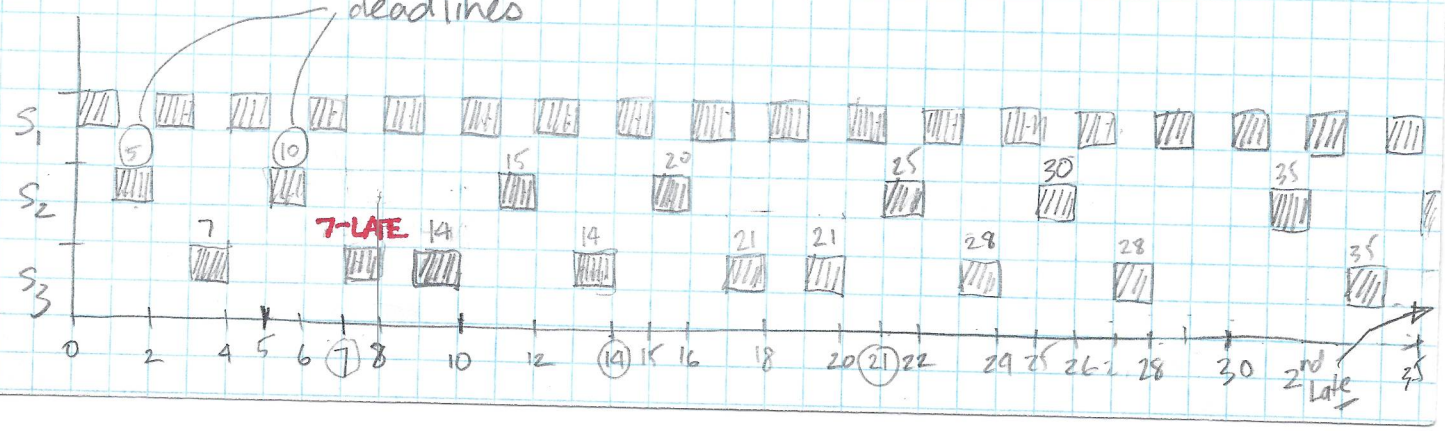
EXAMPLE

Suppose there are three tasks, S_1, S_2 and S_3, characterized as follows:

task	T_i	C_i
S_1	2	1
S_2	5	1
S_3	7	2

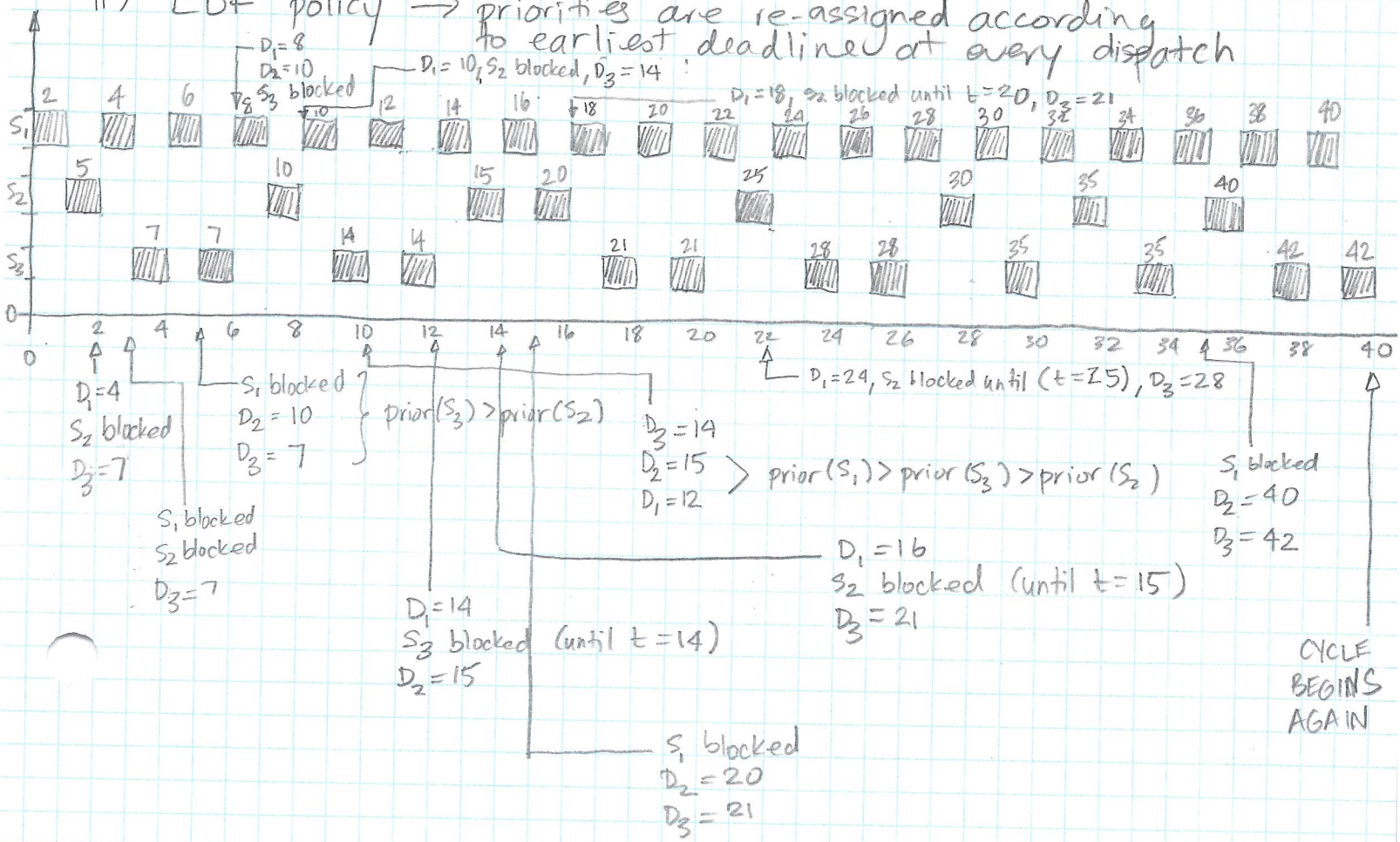
Produce timing diagrams of the RM policy scheduling and EDF policy scheduling.

i) RM: priority (S_1) > priority (S_2) > priority (S_3) ($\because T_1 < T_2 < T_3$)



- as we can see, RM policy produces two late errors for task S_2 in our timing diagram (one error is not shown, just to the right of $t = 37$ units)

ii) EDF policy → priorities are re-assigned according to earliest deadline at every dispatch



$D_1 = 4$, S_2 blocked, $D_3 = 7$

S_1 blocked, S_2 blocked, $D_3 = 7$

S_1 blocked, $D_2 = 10$, $D_3 = 7$

prior(S_3) > prior(S_2)

$D_3 = 14$, $D_2 = 15$, $D_1 = 12$

$D_1 = 14$, S_3 blocked (until $t = 14$), $D_2 = 15$

$D_1 = 16$, S_2 blocked (until $t = 15$), $D_3 = 21$

S_1 blocked, $D_2 = 20$, $D_3 = 21$

$D_1 = 24$, S_2 blocked until ($t = 25$), $D_3 = 28$

S_1 blocked, $D_2 = 40$, $D_3 = 42$

prior(S_1) > prior(S_3) > prior(S_2)

CYCLE BEGINS AGAIN

- as we can see, where RM (fixed priority) fails, the dynamic-priority scheme EDF succeeds (i.e., there are no missed deadlines).

- Q: If EDF works so well, why don't we use it all the time?

A: 1) there may be a little more overhead in dynamic-priority policies compared with fixed-priority ones.

2) in an overload situation (i.e., deadlines are being missed) whereas in RM only lower priority tasks are affected, in EDF it is difficult to predict which tasks will miss their deadlines — potentially catastrophic failures (many tasks missing deadlines) can occur!

3) because of these issues, dynamic priority scheduling is usually restricted to soft real-time systems.

Homework

1) read first three chapters of Richard Barry's Mastering the FreeRTOS Real-Time Kernel
2) order & receive your LPC1769 eval kit
3) download & install the MCU Xpresso IDE