Gang FTP scheduling of periodic and parallel rigid real-time tasks

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Introduction

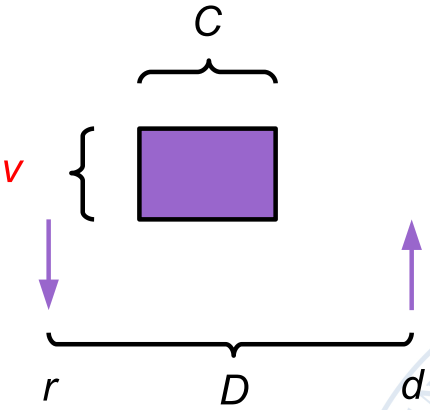
Our objectives:

- Explore the theory of *parallel tasks*, and *Gang scheduling*
- Provide *schedulability tests* for various kinds of Gang schedulers

Why?

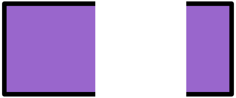
- Parallel tasks are coming on real-time/embedded systems (energy efficiency)
- Very few results in the literature

Task model

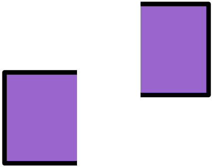


- *n* *(rigid) parallel* (*v*), *periodic* (T), *constrained deadline* (D ≤ T) tasks
- *m* *identical* processors

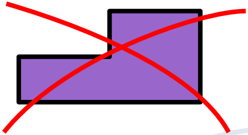
Task model



Preemptive

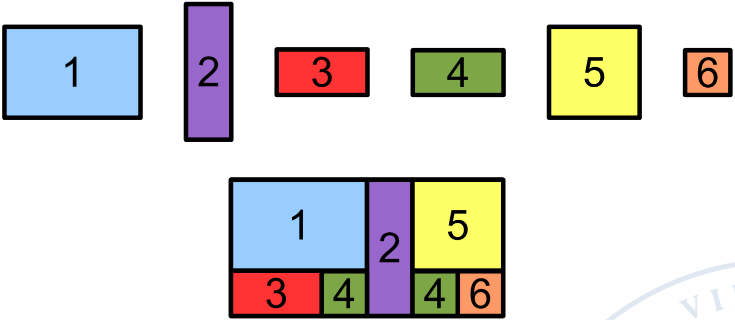


Migrations



Rigid
(not malleable/moldable)

Gang FJP scheduler



Gang FJP scheduler

1. Pick the highest priority job
2. If it fits, start it now
3. Start again with the remaining jobs

Schedulability test

Predictability

Predictability

Schedulable for WCET ⇒ Schedulable

+ Feasibility interval $[A, B]$

Feasibility Interval

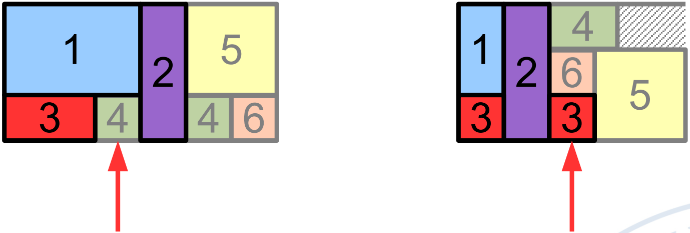
Schedulable in $[A, B]$ ⇒ Schedulable forever

= Schedulability test

Schedulability test

Simulate the system in $[A, B]$ with WCET

Deadline miss



⇒ Gang FJP not predictable!

One of the problems: priority inversion (slack introduces new preemptions)

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- Possibilities
- Parallel Monotonic
- Idling FJP Scheduler
- Limited Gang FJP Scheduler
- Limited Slack Reclaiming

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Making the system predictable

We propose several solutions making the system predictable:

- Avoiding priority inversion
- Not using the slack
- Using the slack “smartly”

Two ways of doing so:

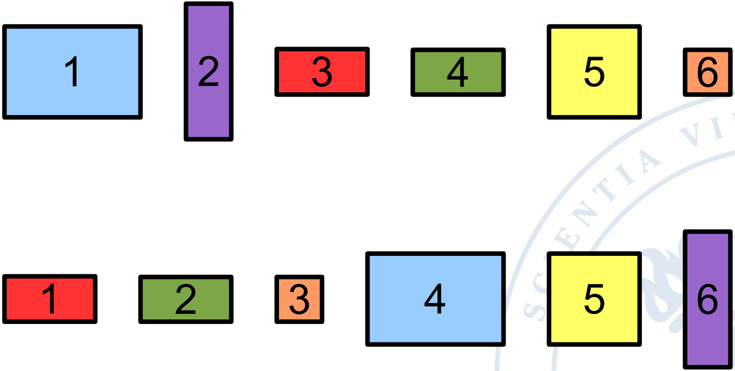
- Constraint the task system
- Constraint the scheduler

Parallel monotonic

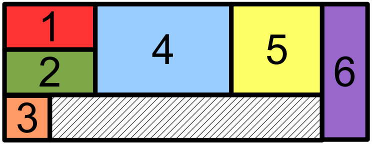
Parallel monotonic FJP assignment

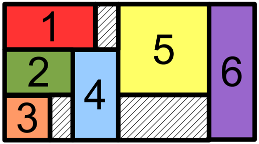
Larger job ⇒ Lower priority

→ High priority to small jobs



Parallel monotonic





We avoid priority inversion!

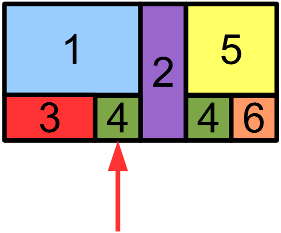
Theorem

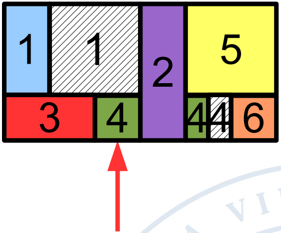
Parallel Monotonic systems are predictable

Idling FJP scheduler

Idling FJP scheduler

Just don't use the slack!





- Still priority inversions, but same behavior as in the WCET case
- Not work conserving!

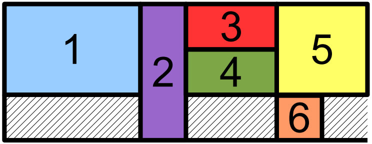
Theorem

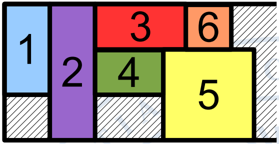
Idling FJP schedulers are predictable

Limited Gang FJP scheduler

Limited Gang FJP scheduler

1. Pick the highest priority job
2. If it fits, start it now
3. *If it fitted in step 2*, start again with the remaining jobs



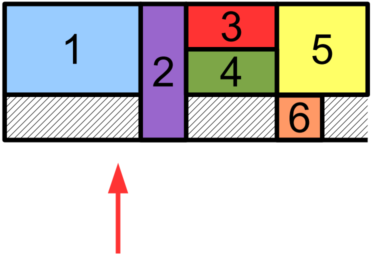


We avoid priority inversion!

Theorem

Limited Gang FJP schedulers are predictable

Limited Gang FJP scheduler

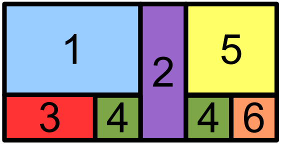


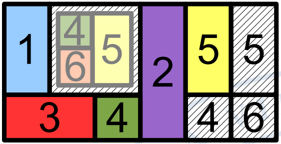
Limited Gang scheduler *less efficient* than “normal” Gang scheduler

Limited slack reclaiming

Gang FJP scheduler with *limited slack reclaiming*

1. While there is no slack, behave as for Gang FJP scheduler
2. Use the slack to run ahead jobs *narrower than the slack*





Still priority inversions, but no “problematic preemptions”

Theorem

Gang schedulers with limited slack reclaiming are predictable

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- Periodicity
- Feasibility interval
- Exact Schedulability Test

4 Conclusions

Periodicity of Gang FTP

Theorem

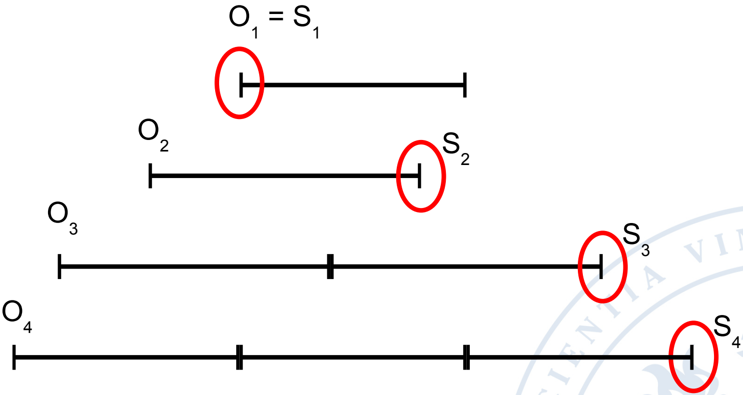
(Whatever) Gang FTP schedulers are periodic (using WCET) :

- With a period $P \stackrel{\text{def}}{=} lcm\{T_1, \ldots, T_n\}$
- Starting from S_n, where:
  - $S_1 \stackrel{\text{def}}{=} O_1;$
  - $S_i \stackrel{\text{def}}{=} \max\left\{O_i, O_i + \left\lceil \frac{S_{i-1} - O_i}{T_i} \right\rceil T_i\right\}, \forall i \in \{2, 3, \ldots, n\}.$

⇒ Same as non-Gang systems!

Going from *sequential* to *parallel jobs* did not change the periodicity

Periodicity



Feasibility interval

Theorem

For *any Gang FTP system* (Parallel Monotonic, Idling scheduler, Limited Gang scheduler, Limited Slack reclaiming scheduler), we can use the following *Feasibility interval*:

$$[0, S_n + P]$$

Exact schedulability test

Predictability

Predictability

OK for Parallel Monotonic, Idling-, Limited Gang- and Limited Slack reclaiming scheduler

+ Feasibility Interval

Feasibility interval

$$[0, S_n + P]$$

= Schedulability test

Schedulability test

Simulate the system in $[0, S_n + P]$ with WCET

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- Future work
- Questions

Conclusions

- We strictly defined *rigid*, *moldable* and *maleable* reccurent tasks
- We provided (and proved) an *exact schedulability test* for several kinds of FTP Gang schedulers
- We studied the *predictability* of those schedulers

Future work

- Extends our results to *moldable* and *maleable* tasks
- Sufficient RM-schedulability test for *sporadic* Gang scheduling
- ...

Questions?