SEVENTH FRAMEWORK PROGRAMME

PROXIMA

Experimental evaluation of optimal schedulers based on partitioned proportionate fairness

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Outline

- Motivation of our work
- Brief recall of RUN and QPS algorithms
- Implementation and evaluation
- Conclusions and future work

Introduction

RUN

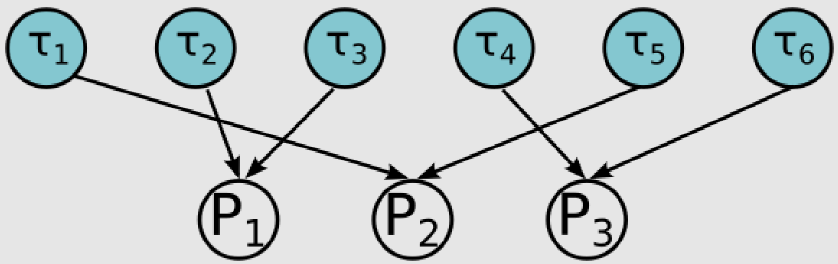
Reduction to UNiprocessor

(RTSS-11)

QPS

Quasi-Partitioning Scheduling

(ECRTS-14)



Optimal multiprocessor scheduling

Not based on proportionate-fairness

Designed to reduce # of preemptions and migrations

On periodic task-sets

Also on sporadic task-sets

Motivation

RUN

QPS

Implemented[1]

on top of LITMUS^RT

Confirming

moderate run-time overhead

in between that of P-EDF and G-EDF

[1] Compagnin, D.; Mezzetti, E.; Vardanega, T., "Putting RUN into Practice: Implementation and Evaluation," (ECRTS-14)

Recall of the algorithms /1

RUN QPS

Off-line phase

Multiprocessor scheduling problem → decomposition → *Uniprocessor* scheduling problems

On-line phase

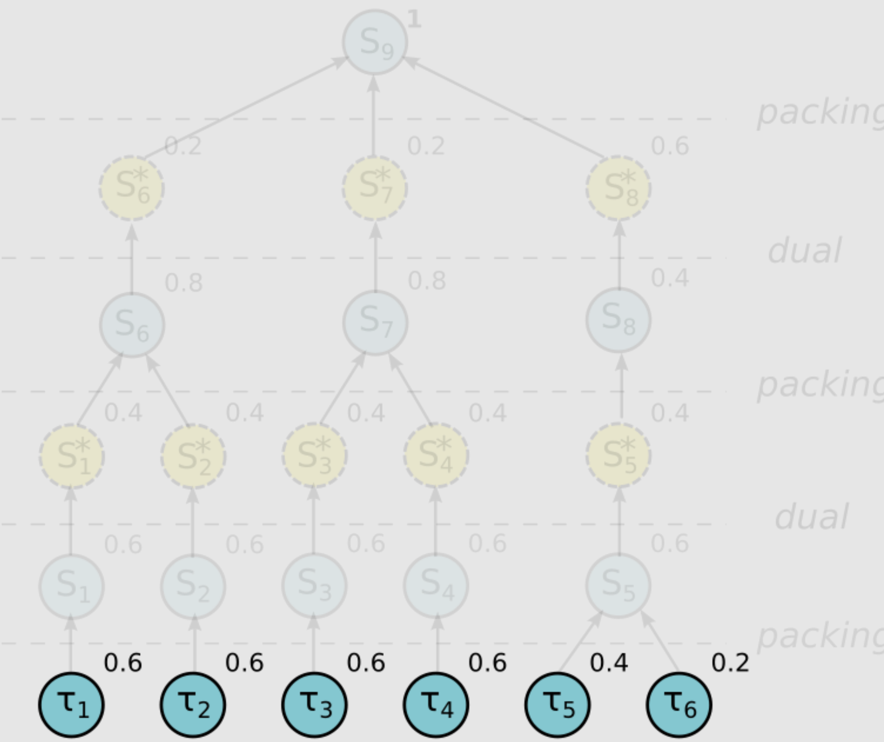
The multiprocessor schedule is “derived” from the corresponding uniprocessor schedule

Recall of the algorithms /1

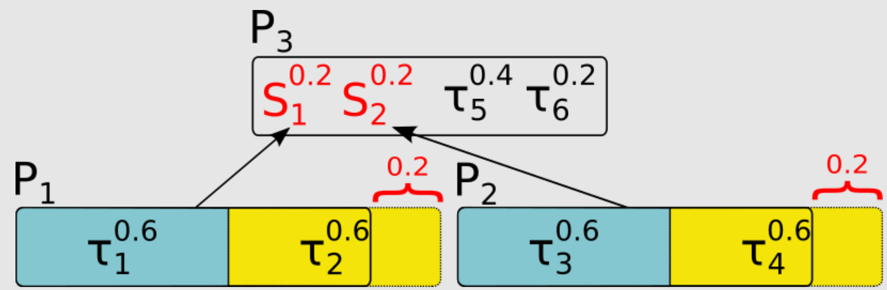
RUN QPS

Off-line phase

Reduction tree



Processor hierarchy



Unitary processor capacity
can be exceeded

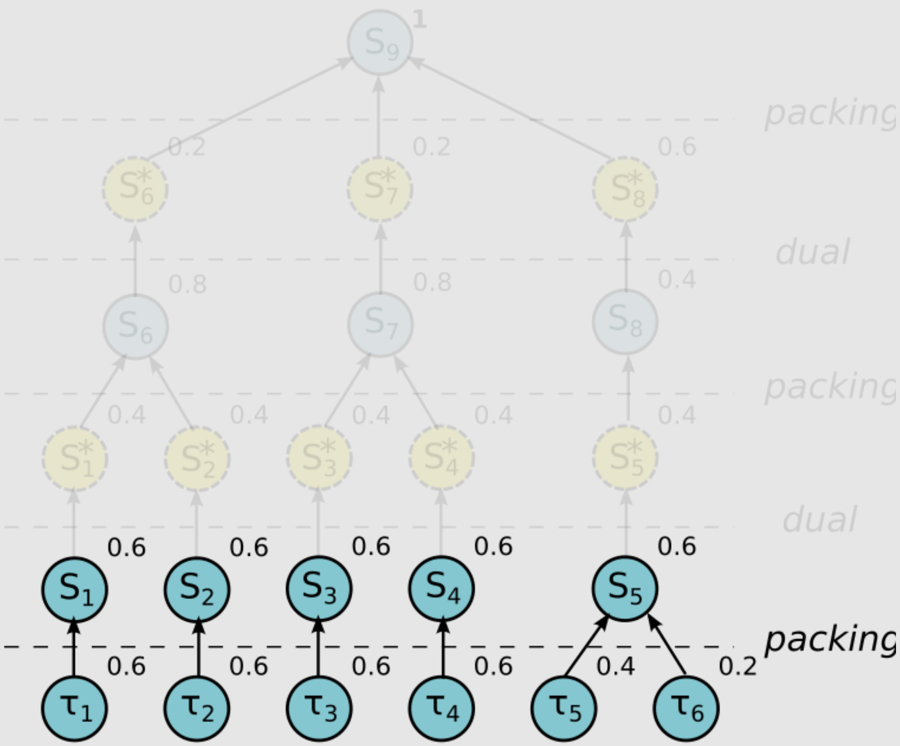
External servers
reserve capacity for exceeding
parts on a different processor

Recall of the algorithms /2

RUN QPS

Off-line phase

Reduction tree



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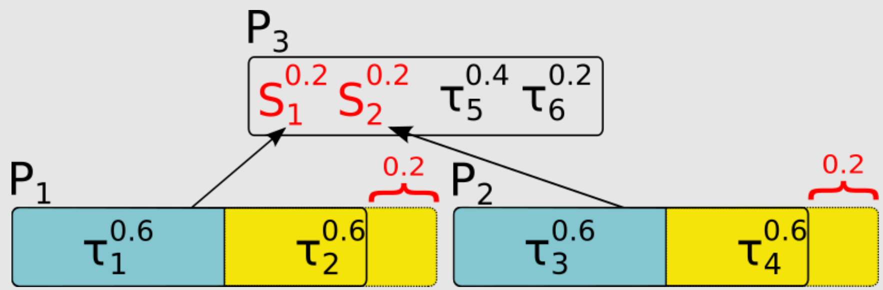

Unitary processor capacity
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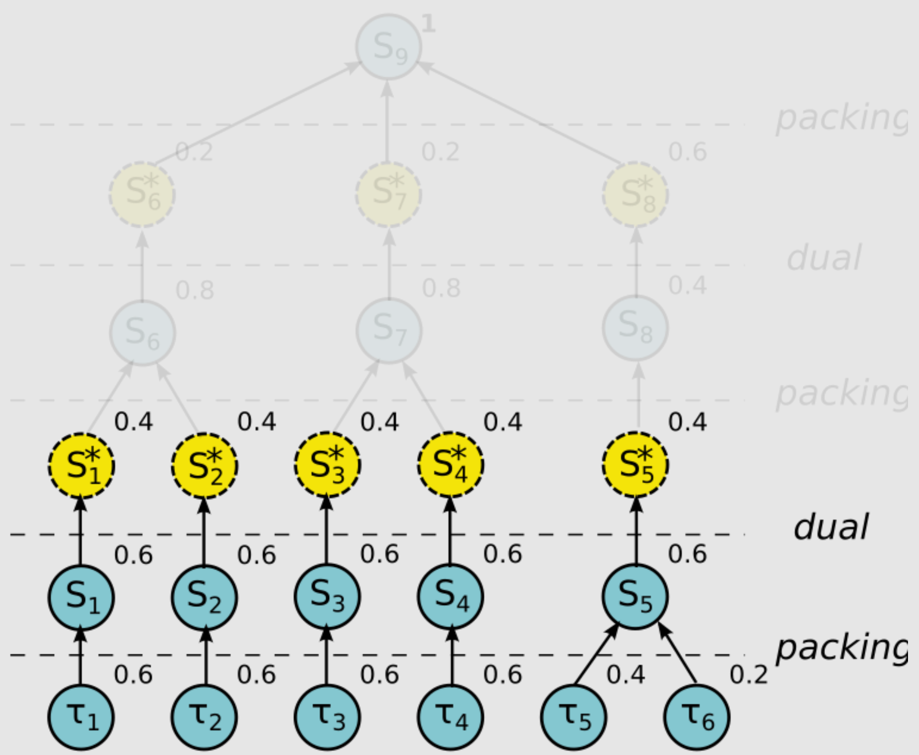
Recall of the algorithms /3

RUN

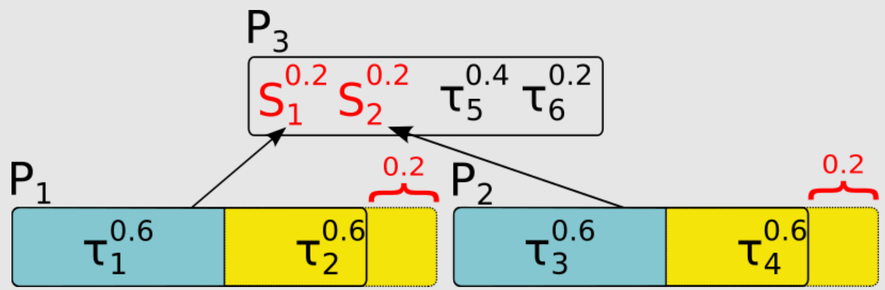
QPS

Off-line phase

Reduction tree



Processor hierarchy



Unitary processor capacity can be exceeded

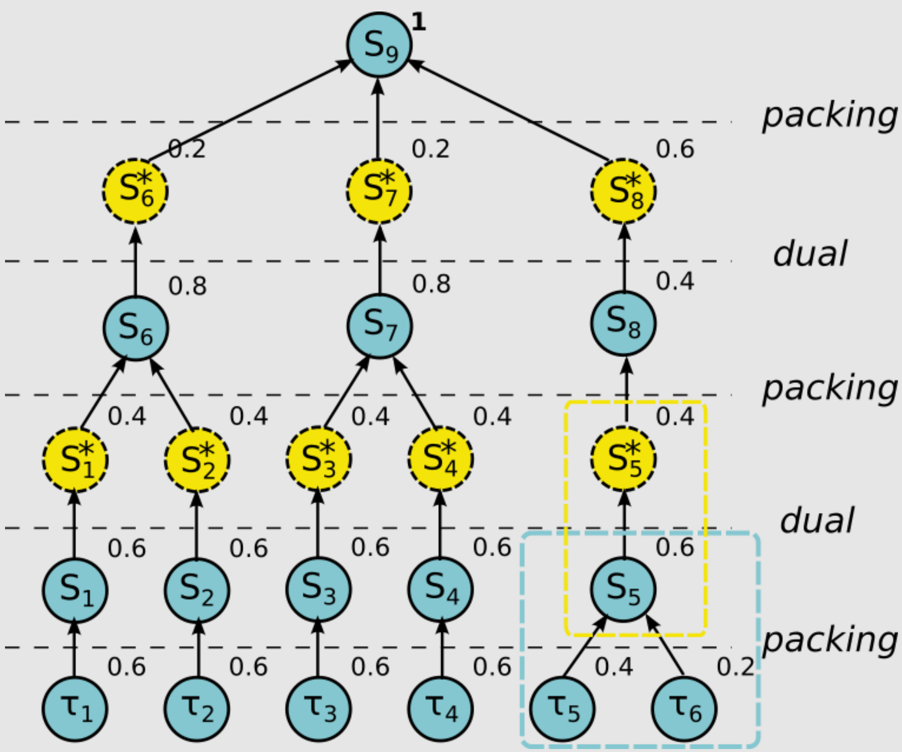
External servers reserve capacity for exceeding parts on a different processor

Recall of the algorithms /4

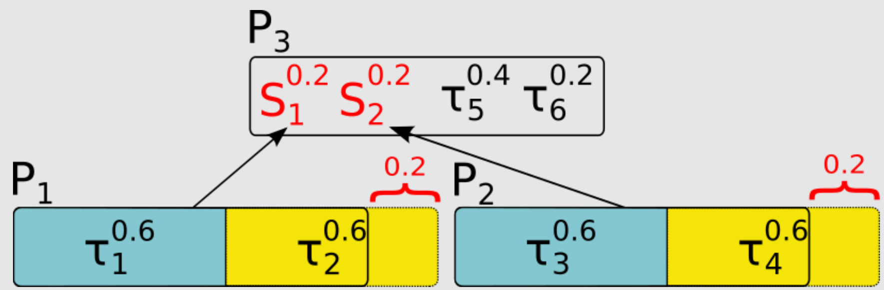
RUN QPS

Off-line phase

Reduction tree



Processor hierarchy



Unitary processor capacity can be exceeded

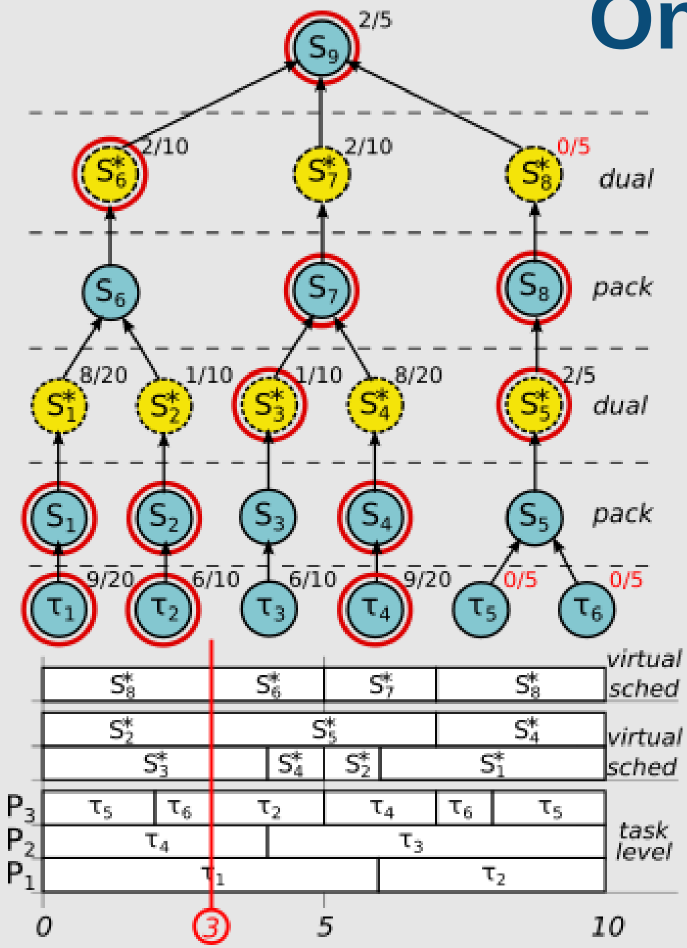
External servers reserve capacity for exceeding parts on a different processor

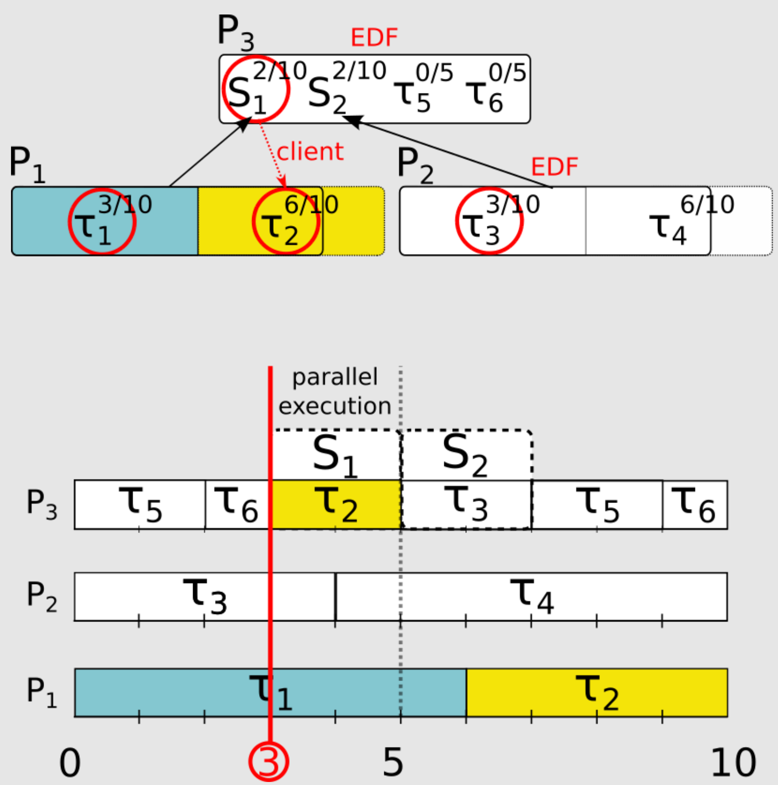
Recall of the algorithms /5

RUN

QPS

On-line phase



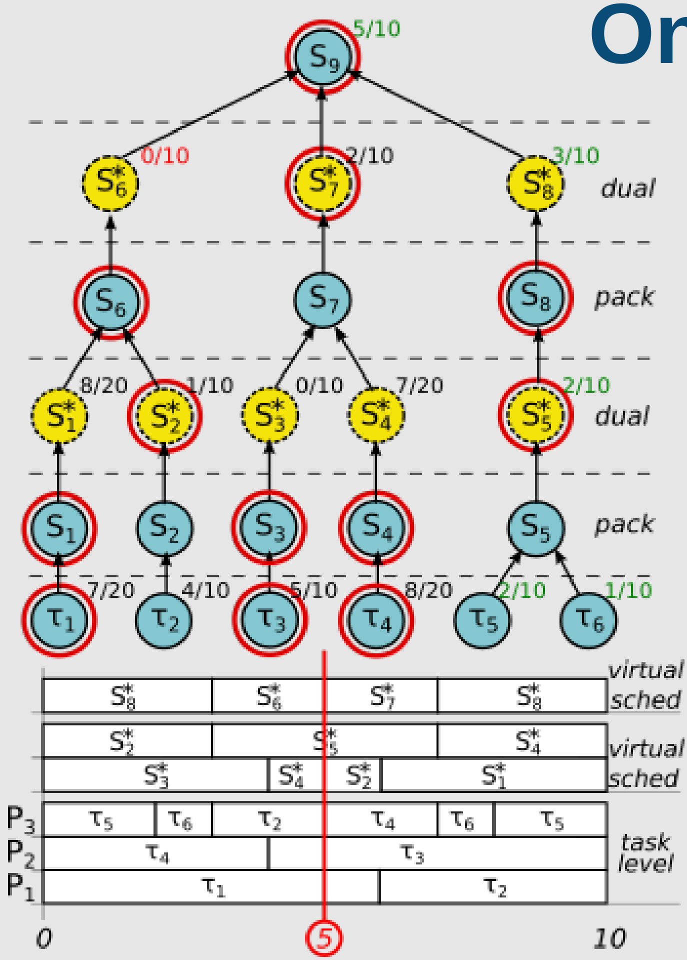


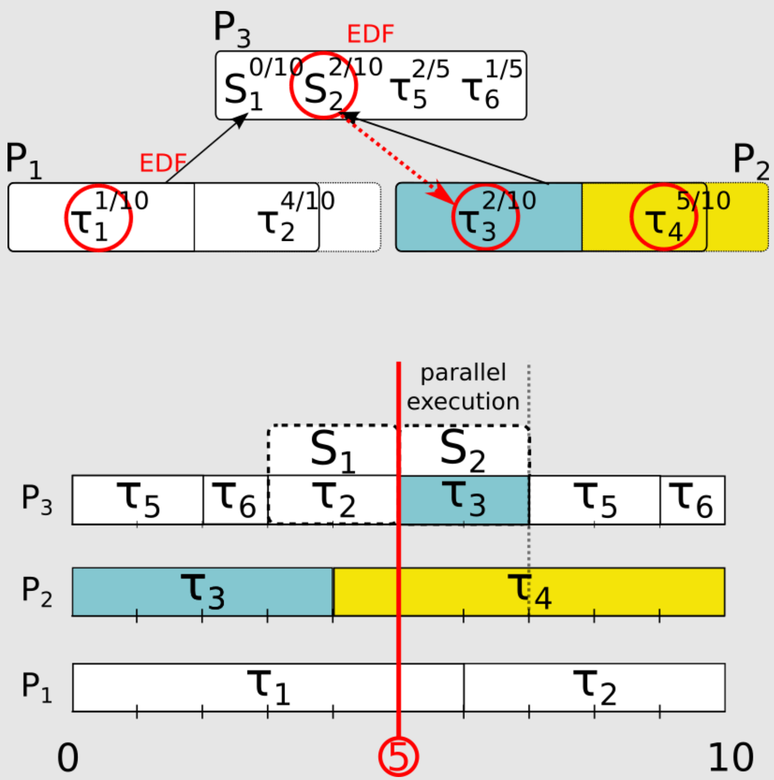
Recall of the algorithms /5

RUN

QPS

On-line phase

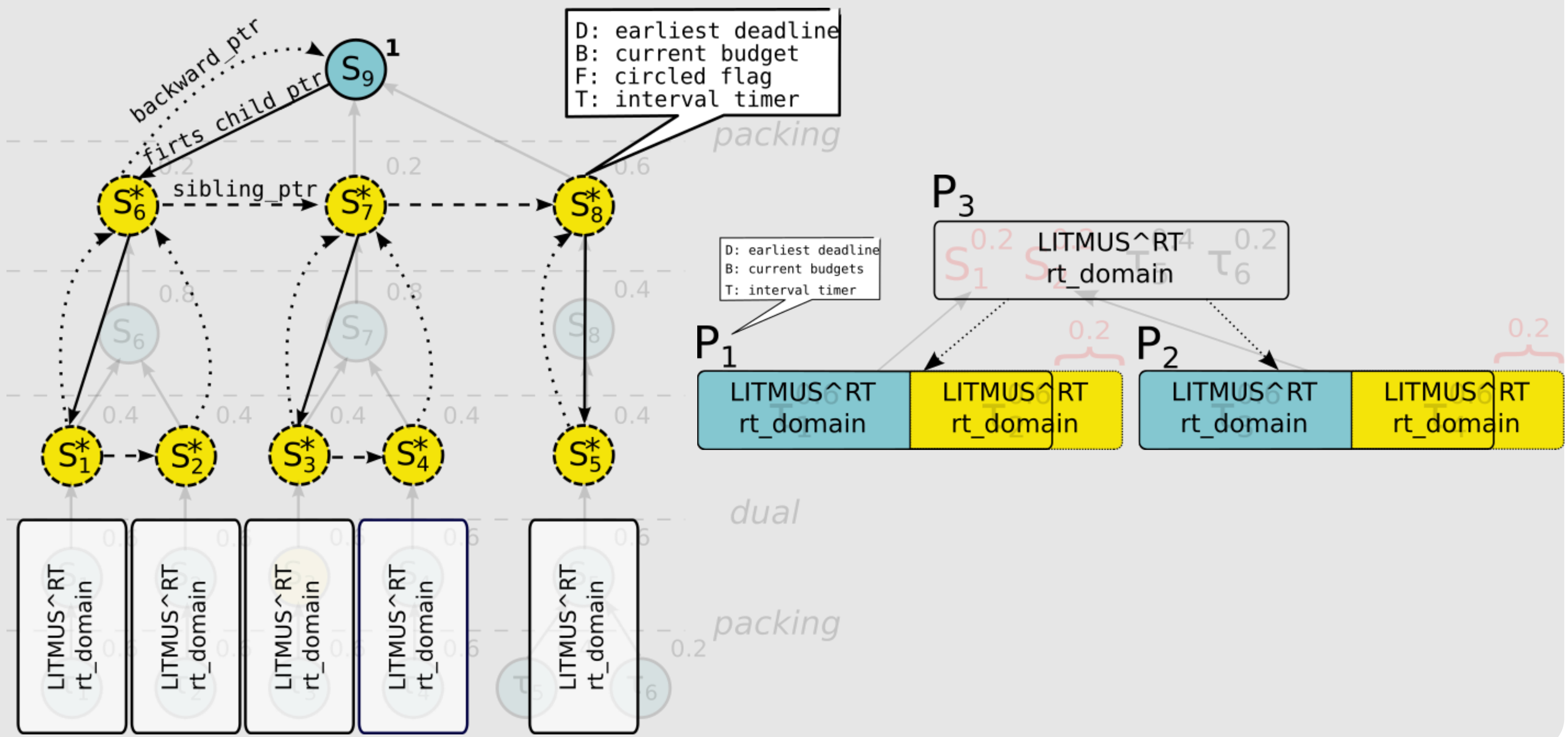




Implementation /1

RUN QPS

Data Structures



Implementation /2

RUN QPS

Notable differences

Global scheduling

- Virtual scheduling
- Compact tree representation
- CPUs are assigned to level-0 servers
- Timers trigger budget consumption events
- Node selection is performed
- Release queue and lock

Local scheduling

- With EDF

Local scheduling + Processor synchronization

- Uniform representation of tasks and servers
- Budgets consistently updated
- Timer triggers budget consumption events
- Per-hierarchy release queue and lock

Implementation /3

RUN QPS

Notable differences

Global scheduling

- Virtual scheduling
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- Release queue and lock

Local scheduling

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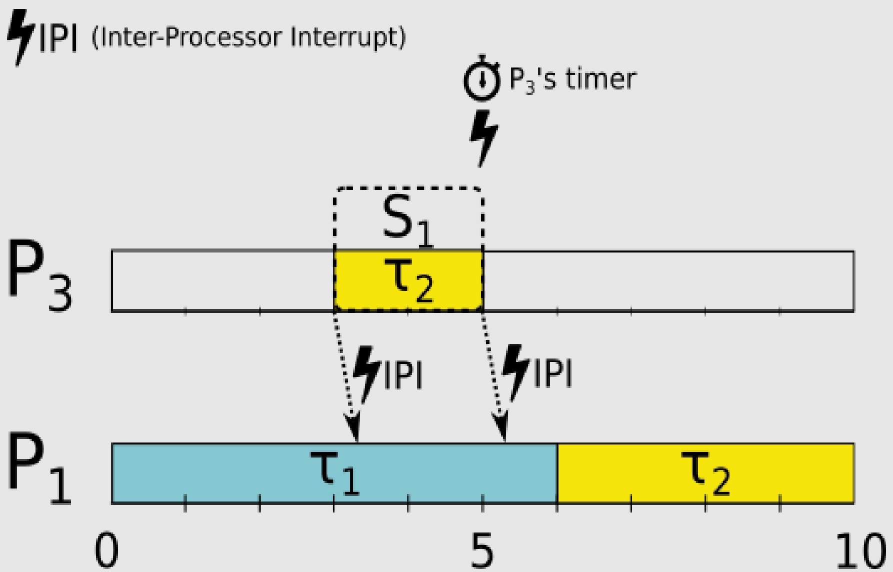
Local scheduling + Processor synchronization



P_3 notifies P_1 of the S_1's execution

Implementation /4

RUN

QPS

Main issues

Overlapping events

- Global events may occur simultaneously
- Unnecessary tree updates

Unnecessary processor synchronizations

Short scheduling intervals

The scheduling primitives might take more time than the budget available for a server

Evaluation

- Empirical evaluation instead of simulation

- Focus on scheduling interference
  - Cost of scheduling primitives
  - Incurred preemptions and migrations

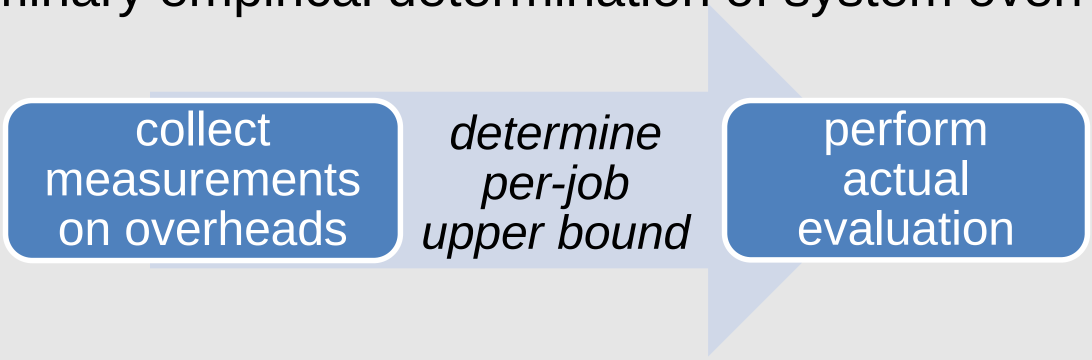
- Evaluation limited to periodic task
  - *External servers* are always “active”
  - Sporadic activations would normally have lower utilization
    - Thus reducing the number of preemptions/migrations

Experimental setup

- LITMUS^RT on a 16-cores AMD Opteron 6370P

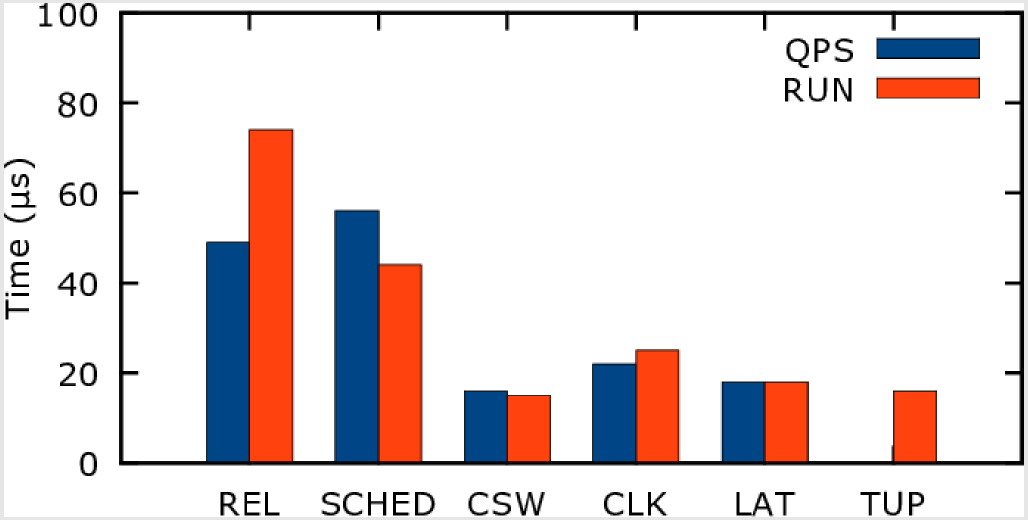
- Exhaustive measurements over the two algorithms
  - Thousand of automatically generated task sets
  - Harmonic and non-harmonic, with global utilization in 50%-100%
  - Stressing both the off-line and the on-line phases

- Two-step experimental process
  - Preliminary empirical determination of system overheads



Primitive overheads and empirical bound

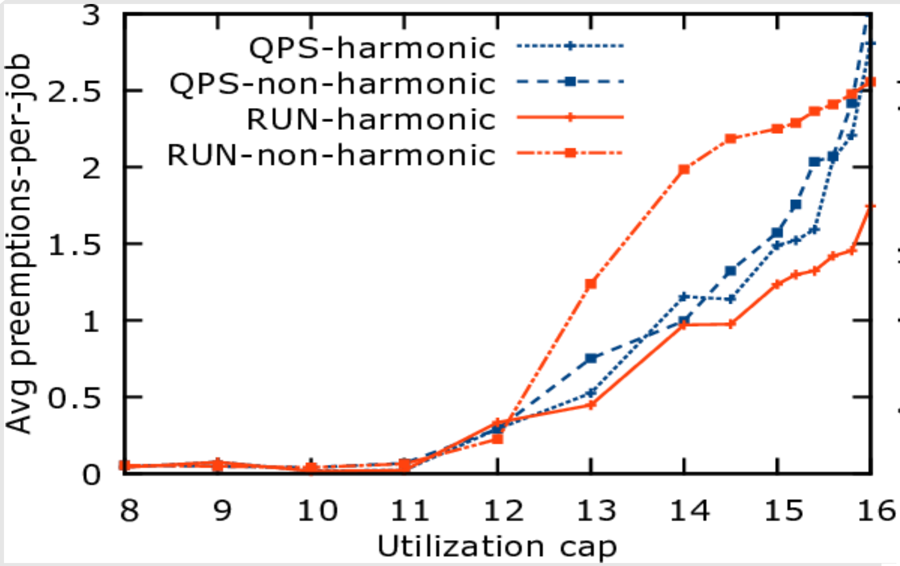
maximum observed overheads

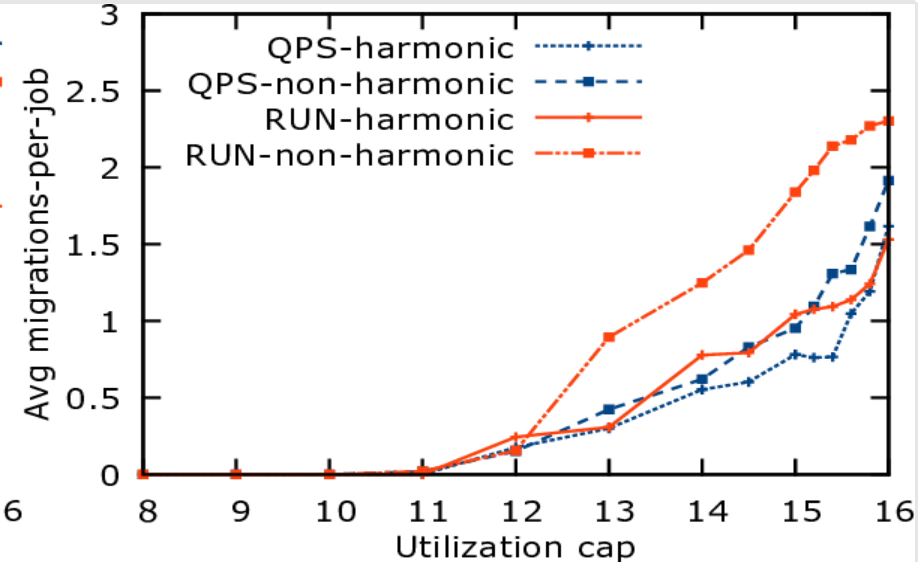


- Expectation was confirmed
  - QPS has lighter-weight scheduling primitives
  - And does not need Tree Update Operations (TUP)

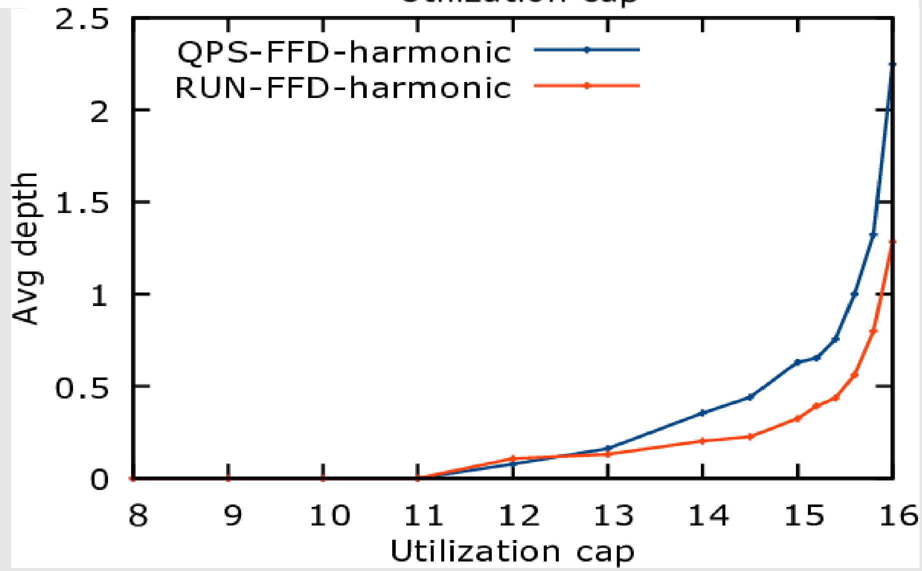
- Empirical upper bound on the scheduling overhead
  - Based on theoretical bounds on the scheduling structures (RUN tree and QPS hierarchy)

Per-job scheduling interference

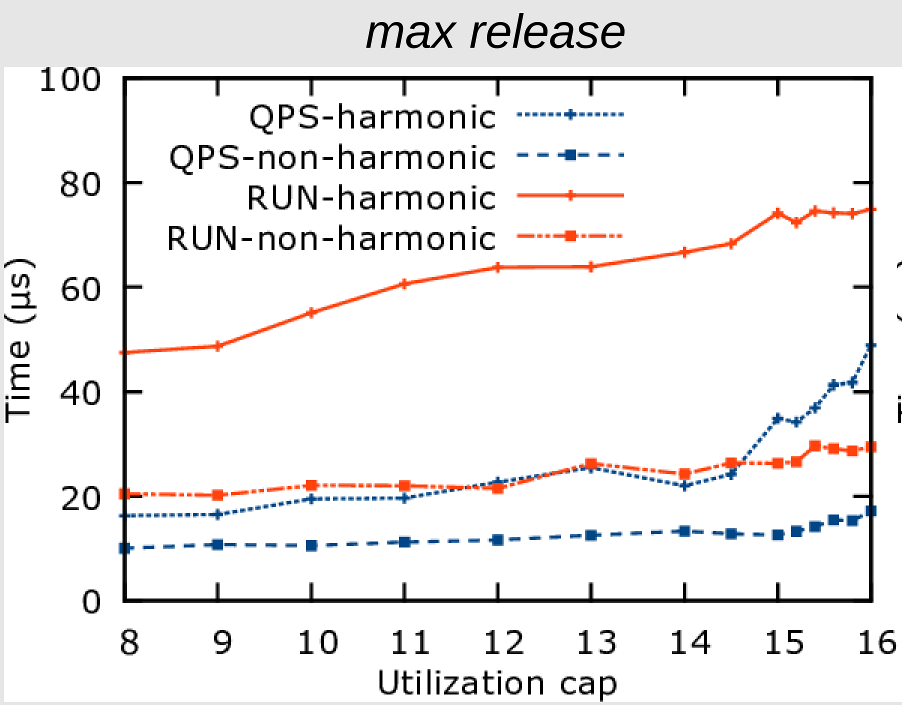


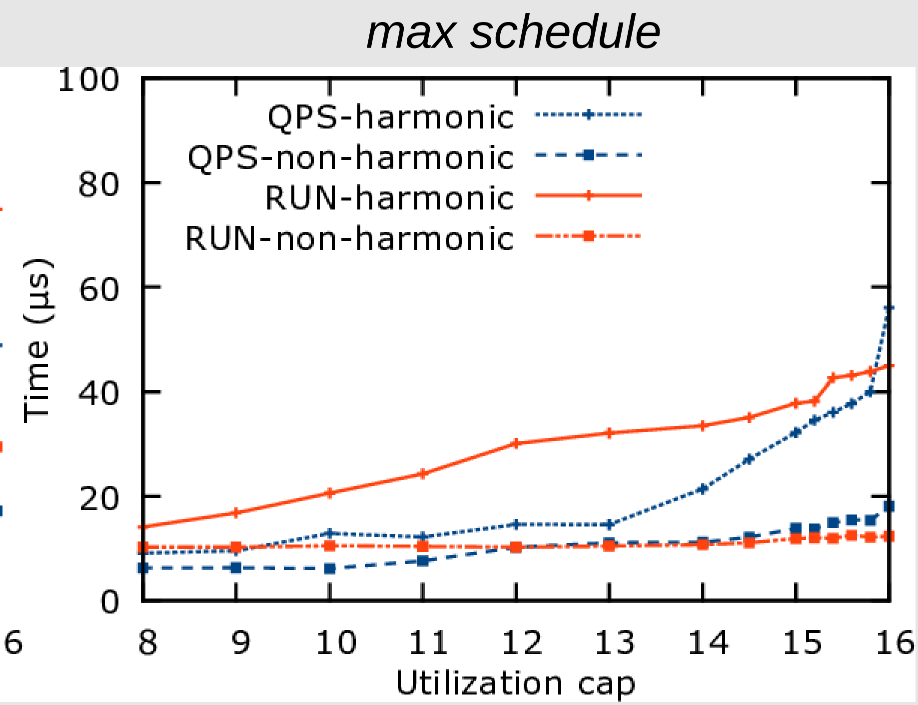


- Determined by preemptions and migrations
- In relation to reduction-tree and processor hierarchy depth



Scheduling primitives

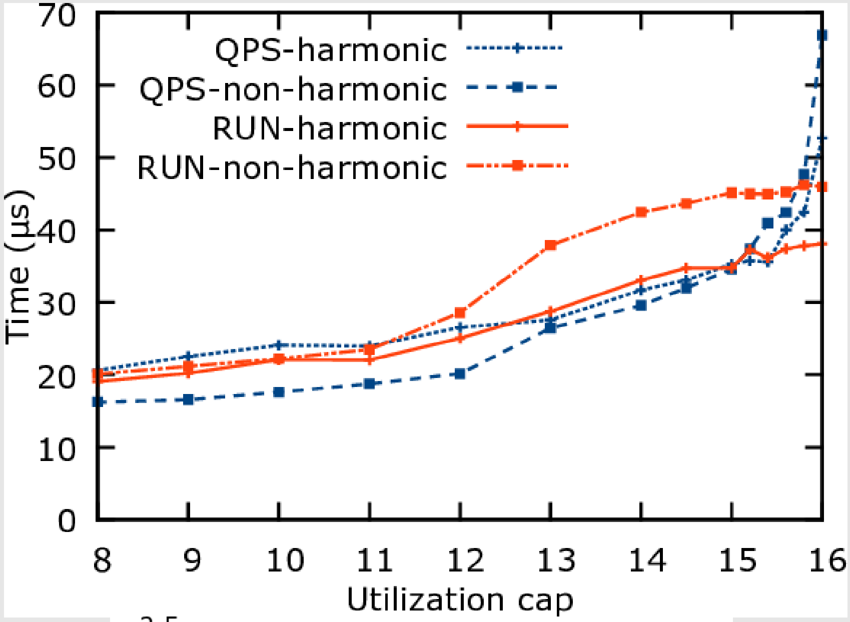




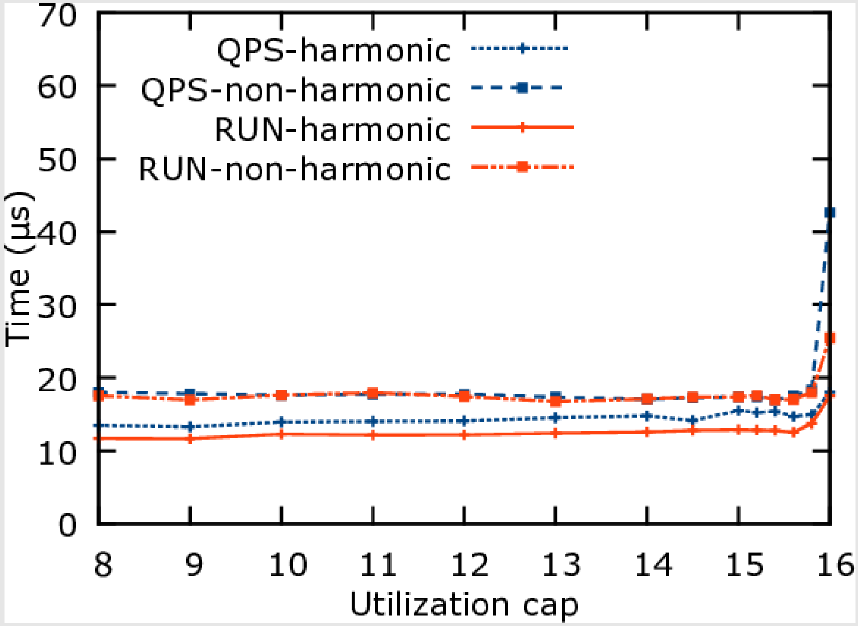
- Maximum observed cost of core scheduling primitives
  - *Release* and *Schedule*
  - Variation under increasing system utilization

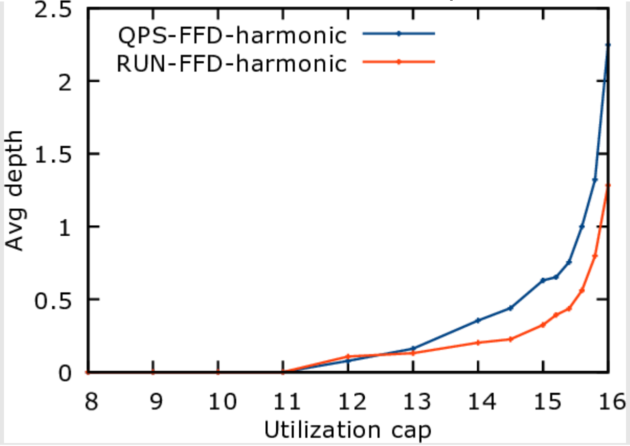
Overall per-job overhead

heavy tasks (utilization [0.5;0.9])



medium tasks (utilization [0.1;0.5])





- QPS is more susceptible to packing than RUN
- Lighter-weight tasks ease the partitioning problem
  - And lead to less complex scheduling structures

Conclusions and future work

- QPS benefits from partitioned scheduling
  - Hence improves over RUN for cost of scheduling primitives
- … but is more susceptible to the off-line phase
  - QPS’s need for processor synchronization hits performance badly with higher processor hierarchies
- RUN exhibits an almost constant overhead
  - Induced by its global scheduling nature
  - Which in turn may penalize it at lower system utilization
- Future work
  - Mainly interested in evaluating how this class of algorithms may behave when the number of processing units increases
    - Considering also how different implementation may affect the algorithm scalability

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