TECHNISCHE UNIVERSITÄT DRESDEN

LUND UNIVERSITY

Models@Run.Time Workshop 2015

USING REFERENCE ATTRIBUTE GRAMMAR-CONTROLLED REWRITING FOR ENERGY AUTO-TUNING

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Presentation Overview

Our **new idea**: Use Reference Attribute Grammars and rewriting for runtime models.

We use

- a **Reference Attribute Grammar (RAG)**
- to create and modify a **runtime model**
- of batch process execution on a compute cluster and
- use **attributes** and **RAG-controlled rewrites** to schedule the system's tasks
- in an **energy-optimized** way.

Outline

Case Study

Solution Background (*RACR*)

Our Solution

Evaluation and Outlook

A Case Study: Scheduling Batch Processes

of Wikipedia Indexing Tasks

Very simple case study to show use of RAGs for runtime model

Task: indexing of text chunks (taken from Wikipedia)

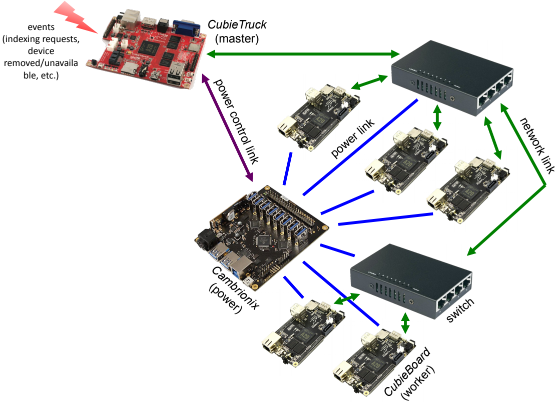
- processing time predictable (proportional to chunk size)
- requests arrive interactive (occur randomly)
- requests have deadline

Energy Optimization: Minimize energy consumption of the indexing system

- System is network of (embedded) computers
- Computers (and connecting switches) can be turned off to save energy

A Case Study: Scheduling Batch Processes

of Wikipedia Indexing Tasks



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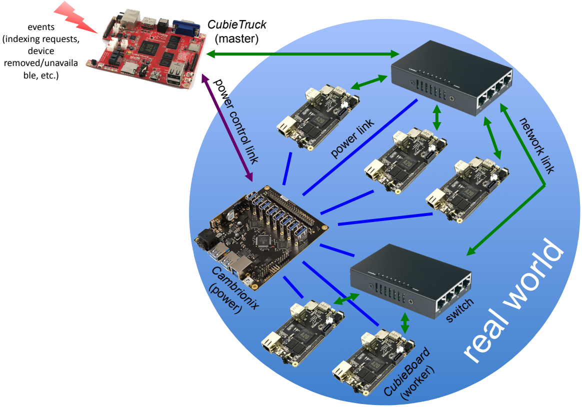

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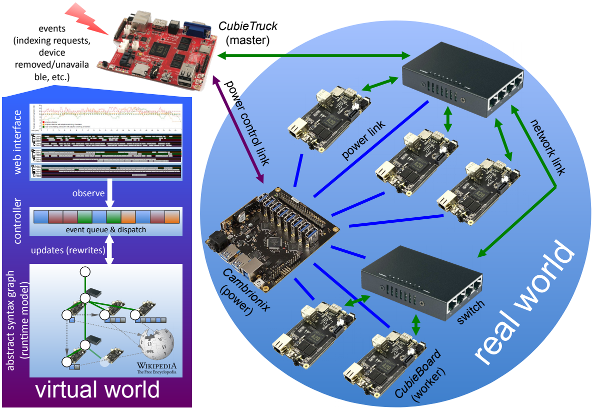

Solution Background

RACR - Reference Attrribute Grammar-Controlled Rewriting

RACR is . . .

- a Reference Attribute Grammar (RAG) system
  - declarative semantics
  - lazy, incremental evaluation
- for RAG-controlled rewriting
  - advanced AST manipulation

Solution Background

RACR - Reference Attribute Grammar-Controlled Rewriting

RAG-controlled rewriting = RAGs + graph rewriting

- reference attribute grammar for declarative **analyses**
  - reference attributes induce sematic overlay graph on top of *abstract sytax tree (AST)*
  - enables deduction *and* analyses of graph structure

  → deduced, memoized *abstract syntax graph (ASG)*
- graph rewriting for ASG **transformations**
  - left hand: ASG pattern (ASTs connected via reference attributes)
  - right hand: manipulations on matched underlying AST

  → ASG changes with AST (updated by RAG)
- seamless combination:
  - use analyses to deduce rewrites
  - rewrites automatically update analyses

  → incremental

Solution Background

RACR - Reference Attribute Grammar-Controlled Rewriting

The Implementation: RACR

- reference implementation of RAG-controlled rewriting in *Scheme* R6RS[1]

RACR contains API for:

- ASG schema definition (AST schema + attribution)
- ASG querying (AST + attributes)
- rewriting:
  - imperative **and/or** RAG-controlled **and/or** fixpoint
  - primitive **and/or** pattern-based
  - **... in any combination!**

`https://github.com/christoff-buerger/racr`

Solution Background

RACR - Reference Attribute Grammar-Controlled Rewriting

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[1] Don't panic! C bindings and .NET bindings are available.

Our Solution

The Grammar

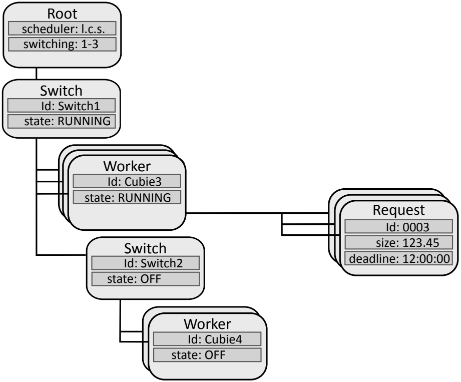
Grammar is encoded in Scheme symbols

- production rule: left side -> right side
- upper case: nonterminals
- lower case: terminals
- repetition (*), inheritance (:)

```
(ast-rule 'Root->scheduler-backupworkers-CompositeWorker)
(ast-rule 'AbstractWorker->id-state-timestamp)
(ast-rule 'CompositeWorker:AbstractWorker->AbstractWorker*)
(ast-rule 'Switch:CompositeWorker->)
(ast-rule 'Worker:AbstractWorker->devicetype-Request*<Queue)
(ast-rule 'Request->id-size-deadline-dispatchtime)
```

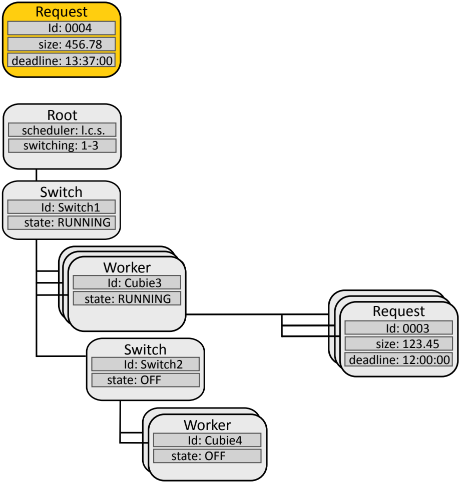
Our Solution

Example AST



Our Solution

Scheduling a Request



Our Solution

Scheduling by Rewriting

Scheduling a new task: rewriting the AST

- insert a new Request node at the right position

```
(rewrite-insert
  (ast-child 'Queue worker) ;list-node to insert into
  index ;position of insertion
  (create-ast spec 'Request (list id size deadline #f)))
```

Our Solution

Attribute-controlled Scheduling

Where to put the new Request?

- evaluate attribute **schedule** to find insertion position
- result is worker and position in worker’s queue
- Attribute depends on terminal **scheduler**

  → scheduler can be exchanged at runtime!

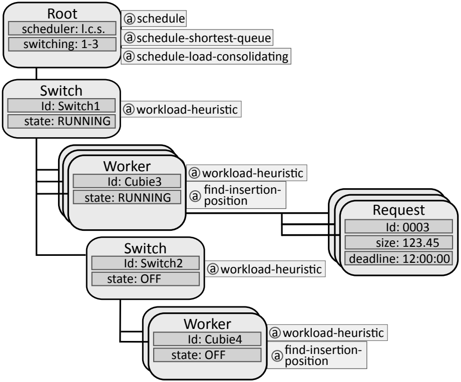
```
(ag-rule schedule
  (Root (lambda (n time work-id load-size deadline)
    (att-value (ast-child ’scheduler n) n time work-id
                load-size deadline))))
```

Our Solution

Two schedulers implemented:

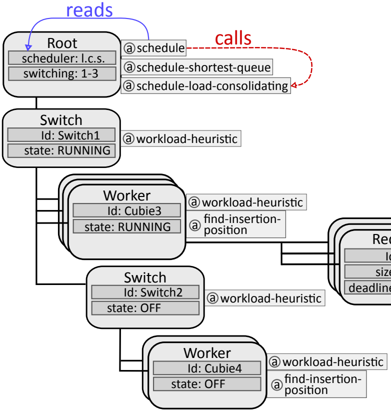
schedule-shortest-queue simple scheduler inserting in shortest queue of any worker

schedule-load-consolidating inserts request in fullest queue while ensuring deadline is kept



Our Solution

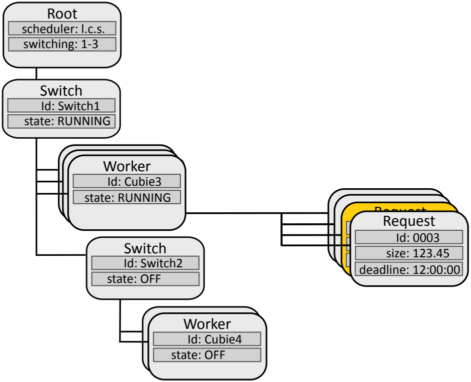
Attribute evaluation



Our Solution

Scheduling a Request

The resulting AST



Our Solution

Saving Energy

Required workers are computed with attributes

- adaptation strategy regularly computes *how many* and *which* workers to switch on or off
- interactive system requires backup workers
- amount of backup workers and adaptation parameters described in AST

Saving energy by switching off workers:

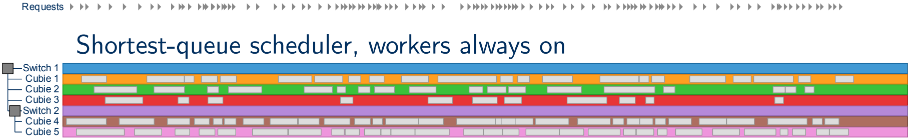
- Try to minimize amount of idle workers
- use adaptation strategy
- use load-consolidating scheduler to minimize required workers

Evaluation

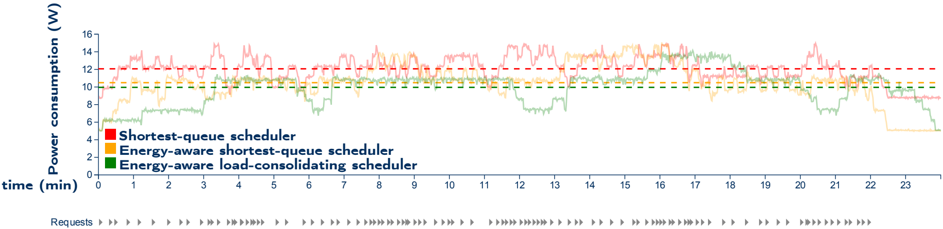
Test setup for measuring energy consumption

- graphical interface to show system state and consumed power
- Scenario generator to run controlled workloads with different settings

Evaluation

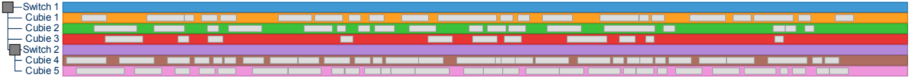

Requests
Shortest-queue scheduler, workers always on
Switch 1
Cubie 1
Cubie 2
Cubie 3
Switch 2
Cubie 4
Cubie 5

Evaluation



🟥 Shortest-queue scheduler
🟧 Energy-aware shortest-queue scheduler
🟩 Energy-aware load-consolidating scheduler

Shortest-queue scheduler, workers always on



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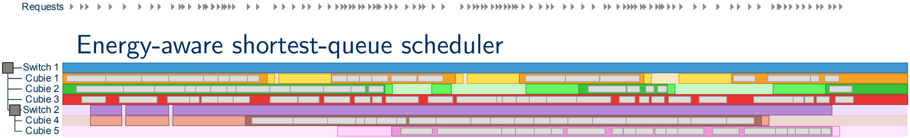
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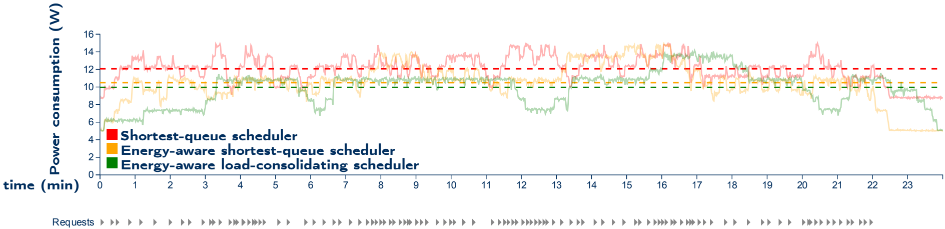
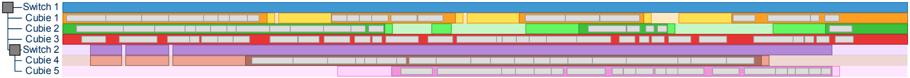
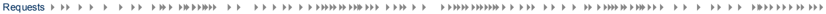


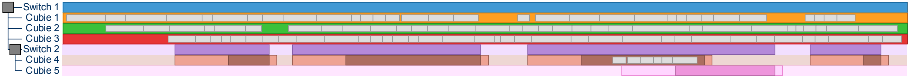
Energy-aware shortest-queue scheduler



Evaluation



Energy-aware load-consolidating scheduler



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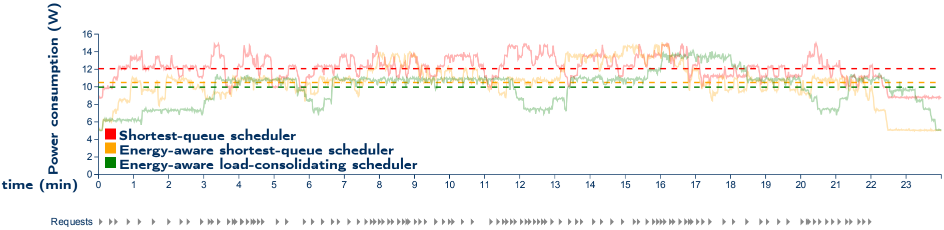
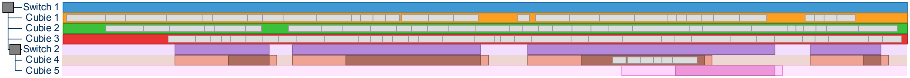


Energy-aware load-consolidating scheduler



Evaluation

Properties of the Solution

- **scalable**: incremental evaluation ensures only necessary attributes are re-evaluated after system change
- **adaptive**: ASG structure can be modified at runtime, schedulers and parameters can be switched
- **fault-tolerant**: system can handle device failures

Evaluation

Results

- Energy-aware shortest queue scheduler saves 13.1% compared to regular shortest-queue scheduler
- Energy-aware load-consolidating scheduler saves 17.5% compared to regular shortest-queue scheduler
- load-consolidating scheduler increases amount of request that can be scheduled

Outlook

Next steps

- heterogeneous architecture
- more interesting network structure
- simulate large systems

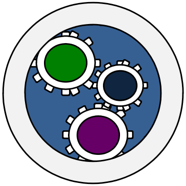
- more case studies for RACR for runtime models

Conclusion

Benefits of RAG-Controlled Rewriting

interactive …

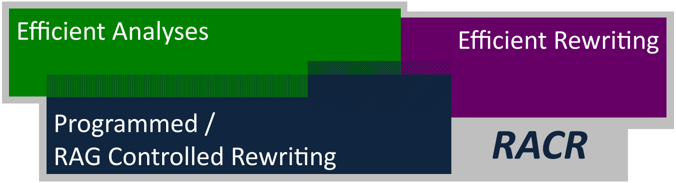
runtime models



incremental reasoning

model transformation

…



Efficient Analyses

Efficient Rewriting

Programmed / RAG Controlled Rewriting

RACR