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Clement Mommessin, Giorgio Lucarelli, Denis Trystram

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Scheduling at the Edge

Clément Mommessin

Giorgio Lucarelli  Denis Trystram

Univ. Grenoble Alpes, CNRS, INRIA, LIG, F-38000 Grenoble, France

June 27th, 2019
Credits: https://www.gironde.fr/actualites/residence-florestine-innovation-technologique-et-sociale
“A disruptive solution to turn IT waste heat into a viable heating solution for buildings.”

The Qarnot platform:

- ~1,000 distributed QRads embedding
  ~3,000 diskless computing units (QMobos)

- ~20 local servers (QBoxes) with disks

- 1 global server (QNode) with a centralized storage server (CEPH)

Credits: https://www.qarnot.com
Qarnot Platform

QNode

Internet

CEPH

Cloud tasks

QBox

IoT tasks

QRad
Qarnot Platform

QNode

Internet

CEPH

Cloud tasks

QRad

QBox

IoT tasks

Heating

requests

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Computing Requests

Cloud tasks:
- Submitted to the QNode
- Have data-set dependencies in the centralized storage (CEPH)
- Have different priorities (low or high)

IoT tasks:
- Submitted to a QBox
- Have data-set dependencies in the QBox disk
- Have different priorities (low, high or very high)
- Should be executed locally

Tasks (= groups of **sequential instances**) are submitted on-line.
Resources appear and disappear over time: the inhabitants decide!

- Available resources when heating is required (QRad is On)
- Unavailable resources when ambient air is too warm (QRad is Off)

Also depends on the task priority

Network uncertainties:
- Link failures
- Congestion/contention
Two-Level Scheduling Problem

The only computing power is in the QRad

Make **global decisions** at QNode-level:
- Decide where to dispatch (groups of) **instances**
- Ensure global load-balancing

Make **local decisions** at QBox-level:
- Schedule instances on QRads
- Regulate room temperature (via DVFS)
- Ensure heating needs are satisfied
Two-Level Scheduling Problem

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Need to reach 100% of platform usage.
⇒ **An idle QRad is a lack of heating**
Multiple Objectives

Different objectives for different users:

- Cloud users: Minimize waiting/completion time of tasks
- IoT tasks: “Nullify” responsiveness
- Inhabitants: Minimize distance to target temperature
- Qarnot: Maximize tasks throughput, minimize lack of heating
Qarnot Solution: Go On-line

Periodic reports (∼30 s) from QBox to QNode with:

- Number of resources available for each task priority
- Free space on disk

QNode-scheduling:

- Sort QBoxes by least available resources first (no temperature knowledge)
- Sort tasks by highest priority first
- For each task, dispatch as much instances as possible

QBox-scheduling:

- Retrieve data-set dependencies
- Schedule high priority instances on coolest QRads
- Schedule low priority instances on warmest QRads
Frequency and temperature regulator in each QRad:

- In general: DVFS on QMobos to adapt power consumption

- When too hot: instances are killed and re-submitted to the QNode

- When too cold (lack of heating): “background” compute-intensive instances are generated (best-effort blockchain mining 😊)
Our objectives

**Main goal:** design, implement and test different placement and scheduling policies at both QNode- and QBox-level.

**Main problem:** testing on a production platform is not conceivable and takes time.
Our objectives

Main goal: design, implement and test different placement and scheduling policies at both QNode- and QBox-level.

Main problem: testing on a production platform is not conceivable and takes time.

⇒ Simulation is what you need!
Simulation Tools

SimGrid\(^1\): Large-scale distributed system simulator with execution and communication models.
→ Used to simulate platform and tasks execution.

Batsim\(^2\): Infrastructure simulator for jobs and I/O scheduling.
→ Used to drive the simulation, submit tasks and communicate with the decision process.

Pybatsim\(^3\): Batsim’s Python API exposing methods to easily communicate with the Batsim process.
→ Used to implement the QNode and QBox schedulers.

\(^1\)https://github.com/simgrid/simgrid
\(^2\)https://gitlab.inria.fr/batsim/batsim/tree/temperature
\(^3\)https://gitlab.inria.fr/batsim/pybatsim/tree/temperature
Developed Extensions

**Temperature model:** to compute the temperature of the QRad and ambient air, based on thermodynamics formulae.

**External events injector:** to replay a machine failure or a temperature change.

**Storage controller:** to manage storage entities and data movements.
Simulation Overview

Simulation process vs Decision process

Simulated platform:
- SimGrid
- Batsim
- Instances executors

SimGrid executor

Instances executors

Simulated platform

Decision process:
- PyBatsim
- QNode Scheduler
- Storage Controller
- QBox Scheduler

Interprocess communication
Variants of the QNode dispatcher:

- *Standard*
- *LocalityBased*
- *Replicate3LeastLoadedDisk*
- *Replicate10LeastLoadedDisk*
- *FullReplicate* (instantaneous transfers)

Standard Qarnot scheduler at QBox-level.

1-week simulation inputs from real logs of Qarnot.
QBox-level Scheduling

List of $n$ instances from Cloud or IoT, with for each instance $j$:
- An estimation of work $Work_j$
- A priority value $w_j$
- A release date $r_j$ (max arrival time of the dependent data-sets)

List of $m$ QRads, with for each:
- A number of QMobos
- A list of possible speeds of a QMobo
- The corresponding power consumption of each speed
- A diagram of target temperature over a day/a week
- The corresponding power diagram over a day/a week
QBox-level Scheduling

Target temperature diagram

Temperature required

20°C (home)

16°C (work)

0  ΔT=0  ΔT=-4  ΔT=0  ΔT=+4  ΔT=0  24

Time of the day

ΔT=0  ΔT=0  ΔT=-4  ΔT=+4  ΔT=0

20°C (home)

16°C (work)
QBox-level Scheduling

Temperature required

Time of the day

ΔT=0
ΔT=-4
ΔT=0
ΔT=+4
ΔT=0

20°C (home)

16°C (work)

Power required

200 W (heating)

60 W (stable)

30 W (stable)

Power diagram

Time of the day

0 24
QBox-level Scheduling

**THE questions to answer:**
- Where to execute an instance?
- When to execute an instance?
- At which speed?

⇒ Similar to power capping problems

**Objectives:**
- Minimize $\sum_j w_j C_j$ (where $C_j$ is the completion time)
- Minimize power consumption distance to the power diagrams
Conclusions and Prospects

Preliminary results:
- Scheduling at the edge depends highly on heterogeneity and dynamicity
- Simulating edge platforms is possible thanks to Batsim/SimGrid
- Data placement is not trivial

Current work:
- Try other placement policies at QNode-level, communicate more with the QBoxes
- Study the QBox theoretical model
- Validate the temperature model
Many Thanks

WE NEED YOU!

Looking for temperature and power consumption of machines/cores in a cluster

This work is supported by the ANR Greco project.

Credits: https://www.la-cnem.org/we-need-you/
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