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Autonomic Approach to the Runtime Management of HPC Cluster Resources

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Autonomic Approach to the Runtime Management of HPC Clusters Resources

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Context & Applicative Problem

Gricad

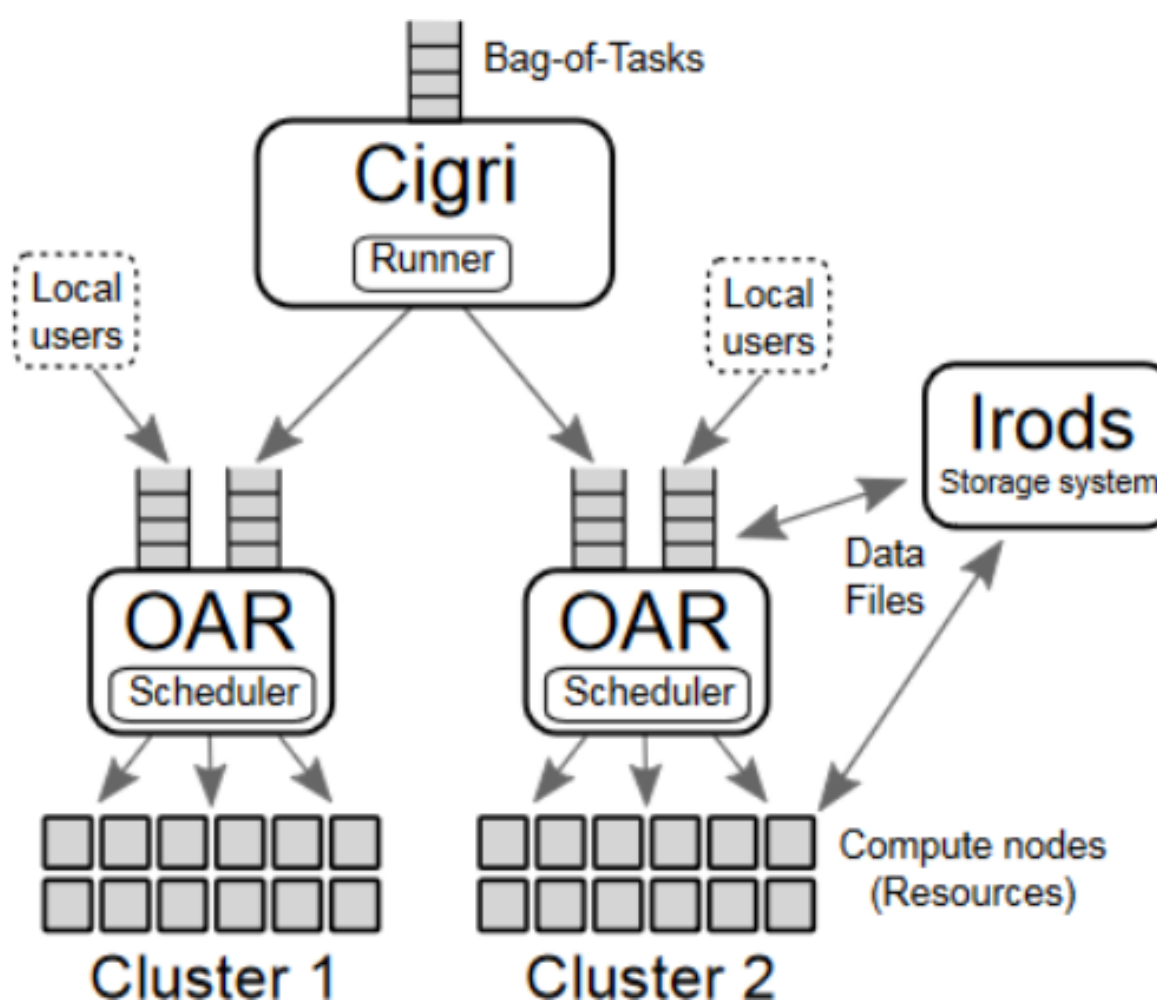


- Grenoble Mesocenter
- 169 TFLOPS
- 5700 CPUs on several clusters
- > 1200 users

Idle HPC Resources \Rightarrow Lost Computing Power
 \hookrightarrow **How to Harvest?**

A Solution: CiGri

- **bag-of-tasks**: many, multi-parametric jobs
- **Best-effort Jobs**: Lowest priority
- **Objective**: Collect grid idle resources in a non-intrusive way for the users

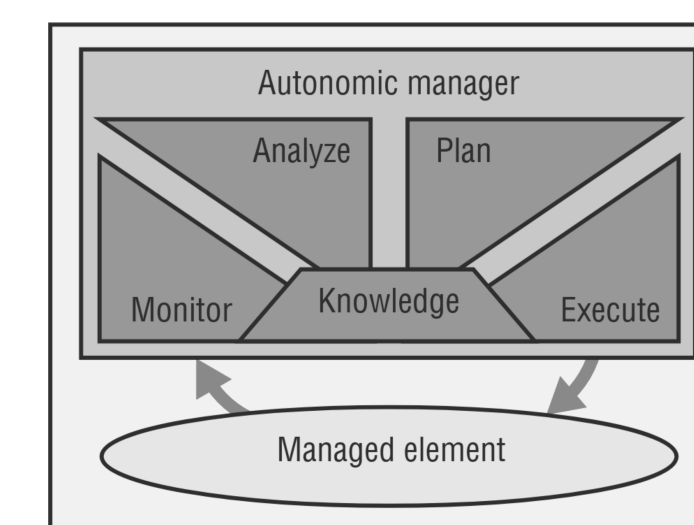


Various Job Behaviours
 \hookrightarrow Variability \Rightarrow Requires **Runtime Management**

MAPE-K Loop & Control Theory

Auto-regulating Dynamical Systems given **high-level objectives**

\hookrightarrow Control Theory as an Interpretation of the MAPE-K Loop



Control Theory drives system to a desired state by adapting inputs while **minimizing delay, overshoot, or steady-state error** and ensuring control **stability**

Perturbations from Harvesting

Cannot simply submit huge amount of jobs.
 \nearrow Harvesting \Rightarrow \nearrow Perturbations (e.g., I/O)
 \hookrightarrow **Trade-off to exploit**

Instrumentation

- **Actuator**: #jobs to submit from CiGri to OAR
- **Sensors**: OAR Waiting Queue length, File-System Load (loadavg)

Controllers

Controller = function between objective (or *Reference*) error and system input.

$$Error_k = Reference - Sensor_k$$

Different types of **Controllers** (PID, RST, MFC)

$$Actuator_{k+1} = K_p \times Error_k + K_i \times \sum_k Error_k + K_d \times (Error_k - Error_{k-1})$$

Response to Perturbations

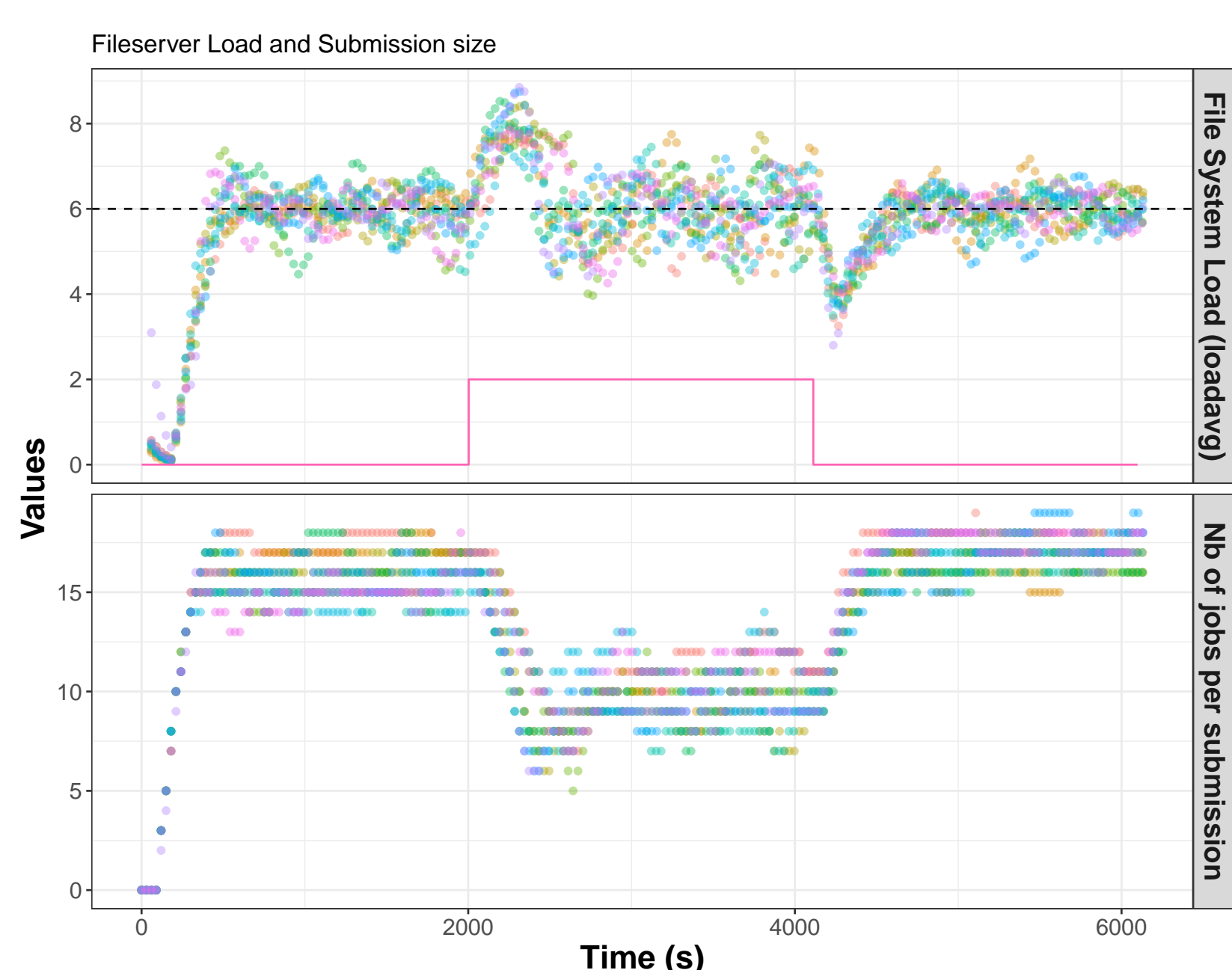


Figure: Response of the closed-loop system (top) to a synthetic step perturbation to keep the load of the File-System around the value 6. Bottom is the number of jobs submitted by CiGri.

Exploiting the Trade-Off

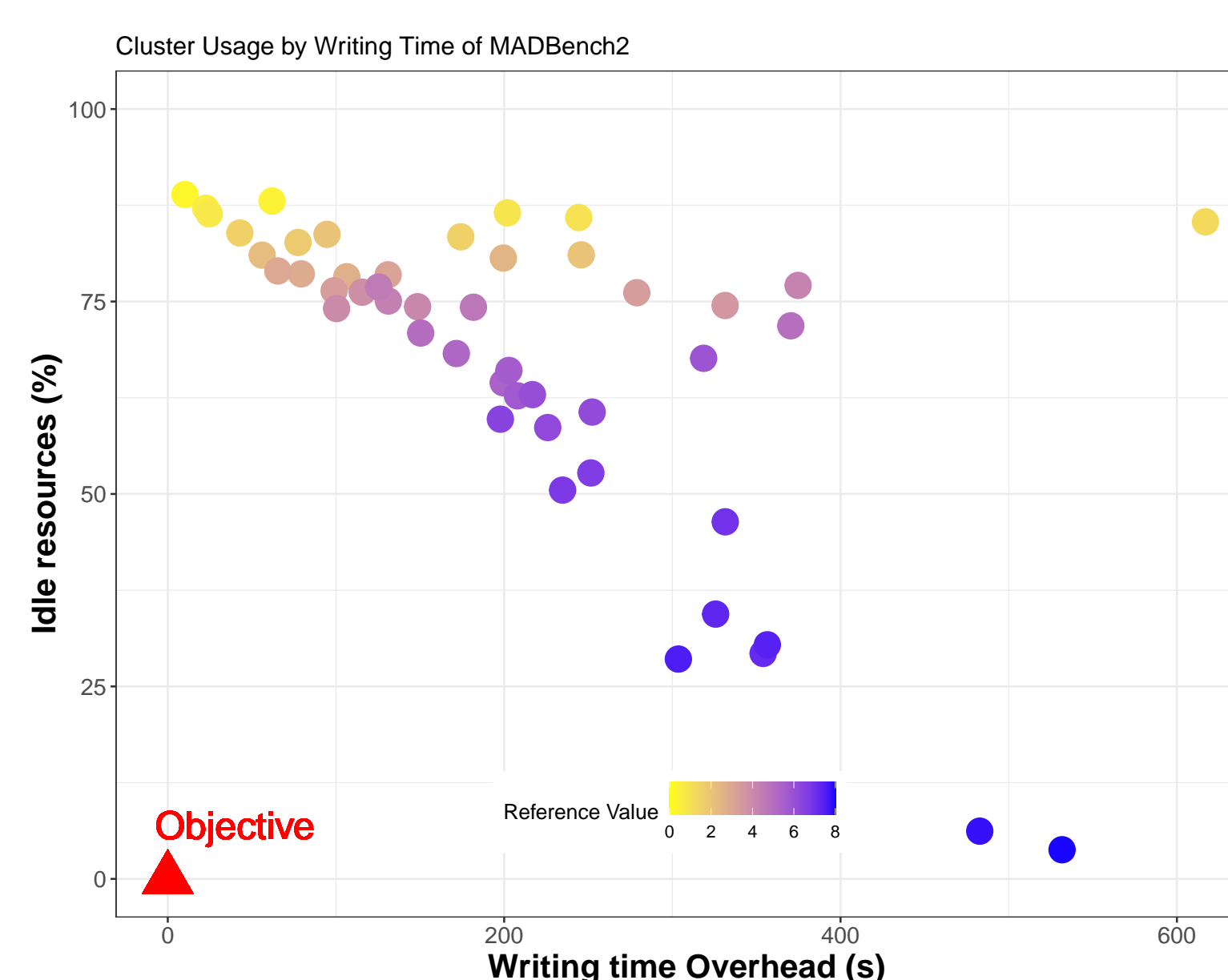
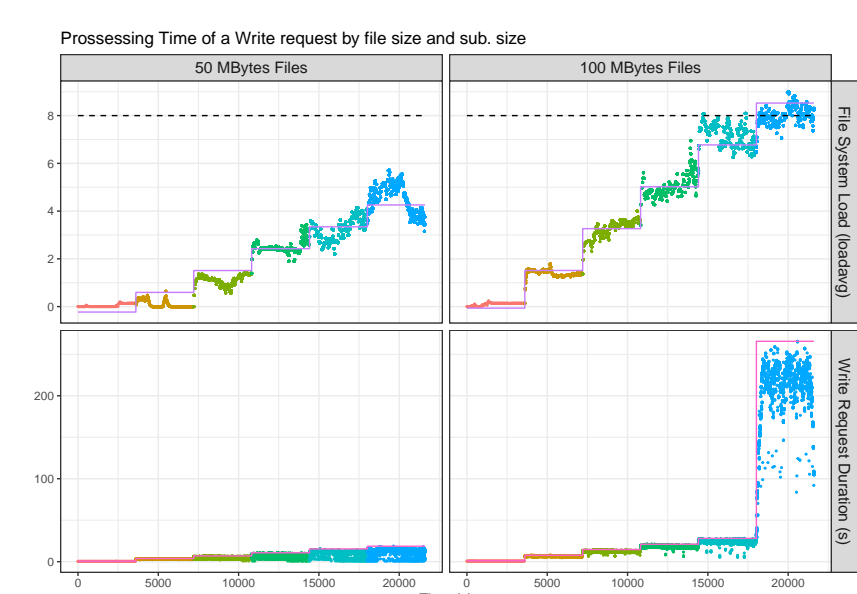


Figure: Writing Overhead of an application (MADBench2 Benchmark) with CiGri based on Reference Value

\hookrightarrow We have **Control over the Degradation and Harvesting** with the choice of Reference Value

Open-Loop & Identification



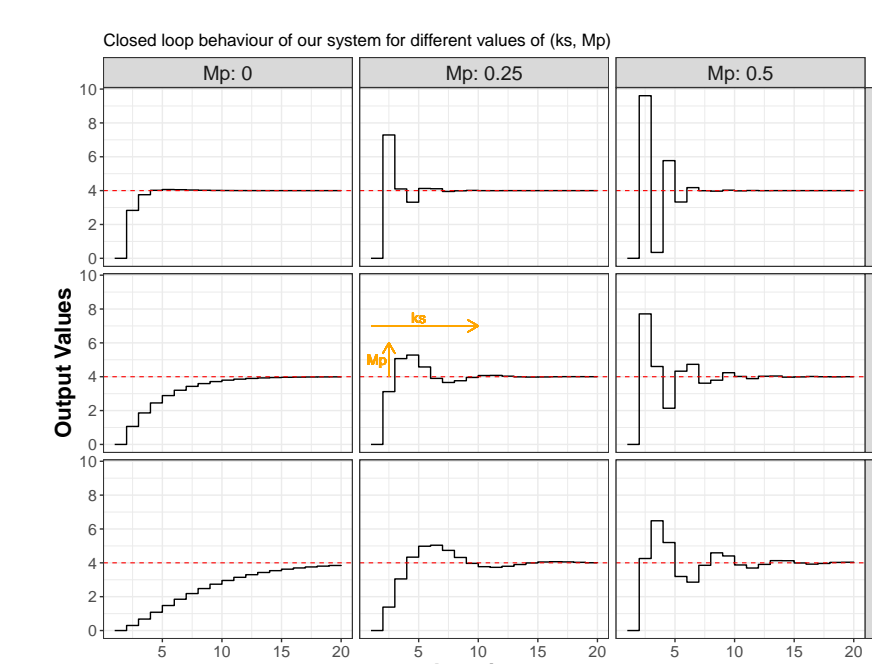
- 1 Vary nb jobs submitted
- 2 Look at FS load
- 3 Model

\hookrightarrow Saturation when File-System Load > 8

Closed-Loop Behaviour

Can pick the **desired system behaviour**:

- k_s : max **time** to steady state
- M_p : max **overshoot** allowed



Non-Intrusive Harvesting means:

- no overshoot
- "fast" response

K_p, K_i, K_d are functions of the model, k_s and M_p

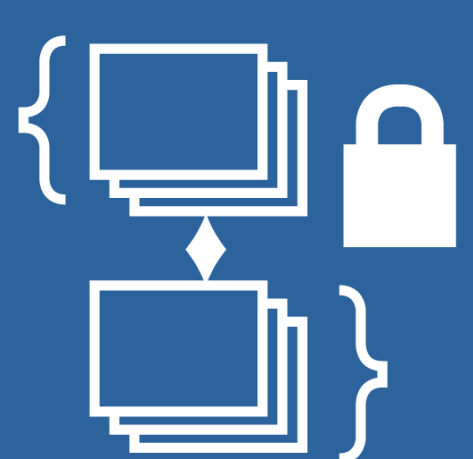
Perspectives

- Adaptive Controllers to deal with different I/O Profiles
- Interaction with Scheduler to anticipate the arrival of new Priority jobs
- Minimize the amount of Best-effort jobs killed (also represents lost computing power)
- Reproducible Experiments with Nix and NixOS

References

Q. Guilloateau, O. Richard, B. Robu and E. Rutten. *Controlling the Injection of Best-Effort Tasks to Harvest Idle Computing Grid Resources*, ICSTCC 2021, hal-03363709

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CTRL-A

Control for safe Autonomic computing systems

Laboratoire d'Informatique de Grenoble



2022