Towards an Energy-Aware Multi-objective Scheduling Policy for Server-based Edge-Cloud Continuum

Compas 2023

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The edge-cloud continuum

Figure 3: Infrastructure of the Edge-Cloud Continuum.
Serverless Computing and the Edge-Cloud Continuum

User's environment view

Developer
D. Scientists
Physicists

Functions
Code

Few
Settings

Platform Provider's View

Scheduler

Edge-Cloud Continuum Infrastructure Level

Cloud clusters

Edge clusters
or Fog

Edge resources

Functions Execution Time

Scheduling Objective

Scheduler

1

2

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Towards a Multi-objective Scheduling Policy for Serverless-based Edge-Cloud Continuum

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Bangalore, India — May 1-4, 2023

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https://andersonandrei.github.io/
https://gitlab.com/andersonandrei/foa-a-multi-objective-scheduling-policy-for-serverless

Thanks to the Intelligence of the Multi-disciplinary Institute on Artificial Intelligence MIAI at Grenoble Alpes (ANR-19-P3IA-0003), to the European Union’s Project H2020 PHYSICS (GA 101017047), and to the Grid’5000 testbed (https://www.grid5000.fr).
Motivation 1 and a multi-objective approach
1. Linear Program (cf. Section IV-B)

2. Minimum Cost Integral Matching (cf. Section IV-C)

3. Container Layer Download Optimization (cf. Section IV-D)

Legend:
- Data
- Process
- Binary Search Controller
- Input
- Output

Assumptions:
1) Functions and environments are independent and known in advance;
2) Their cost and processing time on each machine are known;
3) The dependency between functions and environments is known.

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Experimental Protocol

- Adaptation of the benchmark FunctionBench \(^1\),
- Deployment of OpenWhisk \(^2\) on GRID5000 \(^3\),
  - Measurement and calibration of results.
- Evaluation of scheduling policies FOA, K8S ImageLocality (baseline):
  - In a simulated environment,

\(^1\) https://github.com/kmu-bigdata/serverless-faas-workbench,
\(^2\) https://openwhisk.apache.org/,
\(^3\) https://www.grid5000.fr.
### Design of Experiments

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Workload Size</td>
<td>200, 600, 1000</td>
</tr>
<tr>
<td>Platform Size</td>
<td>100, 300, 500</td>
</tr>
<tr>
<td>Heterogeneity Level</td>
<td>3, 5, 7</td>
</tr>
<tr>
<td>Scheduling Policies</td>
<td>FOA, <em>K8S ImageLocality</em></td>
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<tr>
<td>Random Seeds</td>
<td>30</td>
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**Table 1** Design of Experiments. Total of 1620 experiments.
## Design of Experiments

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**Table 1**: Design of Experiments. Total of 1620 experiments.

<table>
<thead>
<tr>
<th>Function</th>
<th>Input Values</th>
<th>Unit</th>
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<tbody>
<tr>
<td>Chameleon</td>
<td>$2.10^3, 3.10^3$</td>
<td>Matrix size</td>
</tr>
<tr>
<td>Float operation</td>
<td>$10.10^7, 20.10^7, 30.10^7$</td>
<td>Operations</td>
</tr>
<tr>
<td>Image processing</td>
<td>$60, 40$</td>
<td>Image size in MB</td>
</tr>
<tr>
<td>Linpack</td>
<td>$5.10^3, 6.10^3$</td>
<td>Matrix size</td>
</tr>
<tr>
<td>Matrix Multiplication</td>
<td>$3.10^3, 4.10^3$</td>
<td>Matrix size</td>
</tr>
<tr>
<td>Model Training</td>
<td>$50, 100$</td>
<td>Dataset size</td>
</tr>
<tr>
<td>Pyaes</td>
<td>$3.10^3, 4.10^3, 5.10^3$</td>
<td>Length of message</td>
</tr>
<tr>
<td>Video Processing</td>
<td>$30, 50, 100$</td>
<td>Video size in MB</td>
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**Table 2**: Functions adapted from FunctionBench.
Experimental results: Linear program trade-off

<table>
<thead>
<tr>
<th>Workload Size = 200</th>
</tr>
</thead>
<tbody>
<tr>
<td>Platform Size = 500</td>
</tr>
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</table>

Amount of Downloaded Data (GB) vs Makespan (Minutes) for different LP Binary Search Iterations.
Conclusions - Part 1

- Cloud greedy algorithms may not profit from heterogeneity,
- FOA outperforms our baseline for both data transfers and makespan criteria, in addition to the system utilization by up to two orders of magnitudes,
- FOA minimizes cold start delays and speed up functions’ execution time,
- However, FOA is very time-consuming.
Motivation 2 = Motivation 1 + Energy Consumption
FOA-e: Function Orchestration Algorithm

Assumptions:

1) Functions and environments are independent and known in advance;
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Energy Consumption on Serverless Platforms

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Energy Consumption on Serverless Platforms

The diagrams show the instant power consumption over time for different functions. The functions include `linpack_5000`, `linpack_6000`, `chameleon_2000`, and `chameleon_4000`. The graphs illustrate how the power consumption varies with time, indicating the energy usage patterns on serverless platforms.
Experimental results: FOA-e Energy Consumption

![Graph showing energy consumption for different platform sizes and workload sizes with FCFS + FCFS CacheLocality and FOA-e + FCFS CacheLocality scheduling policies.

Platform Size = 100
Platform Size = 300
Platform Size = 500

Energy Consumption (kWh)

Workload Size

Scheduling Policy

- FCFS + FCFS CacheLocality
- FOA-e + FCFS CacheLocality

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Work in progress:

- We have implemented FOA-e to be executed in K8S,
- We have contributed to an Open-Source project called Kepler that measures the energy consumption of k8s components (containers, pods, nodes, etc).
Future Work

- To improve FOA’s model and try other linear programs’ solvers,
- To study applications that can be modeled as workflows of serverless functions,
- To continue the investigations towards the reduction of energy consumption on serverless,
- To add both schedulers in the PHYSICS platforms,
- To include and use Kepler for a continuous measurement of the energy consumption,
- To perform experiments of k8s platforms to compare with the simulations and with default k8s scheduler.
Thank you for your attention! Any question?

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