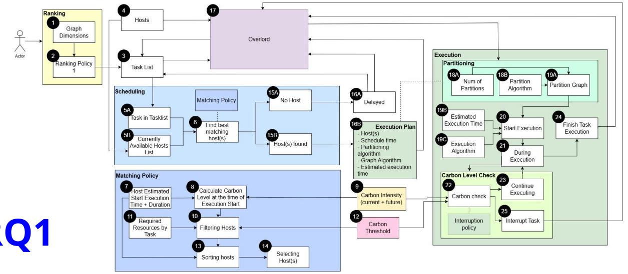
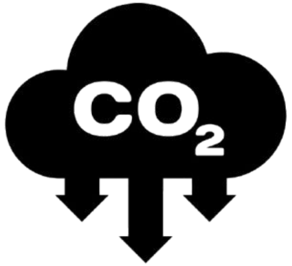
An analysis of the performance and carbon footprint of workloads in datacenters using serverless models in simulation



RQ1

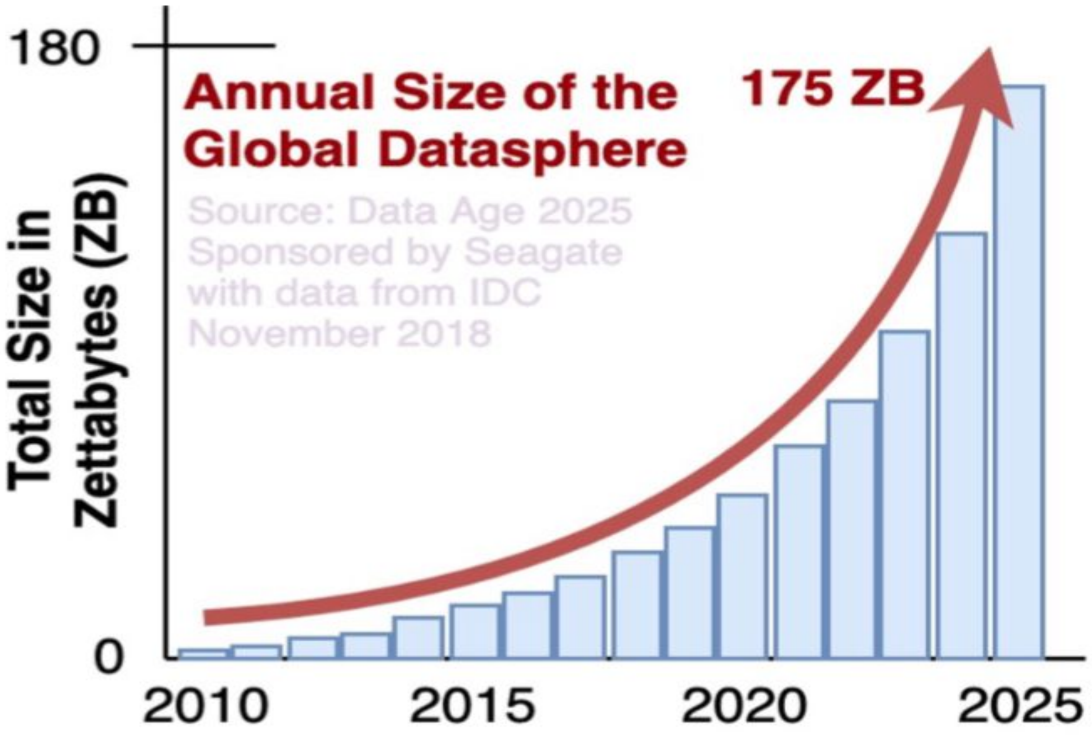


RQ2

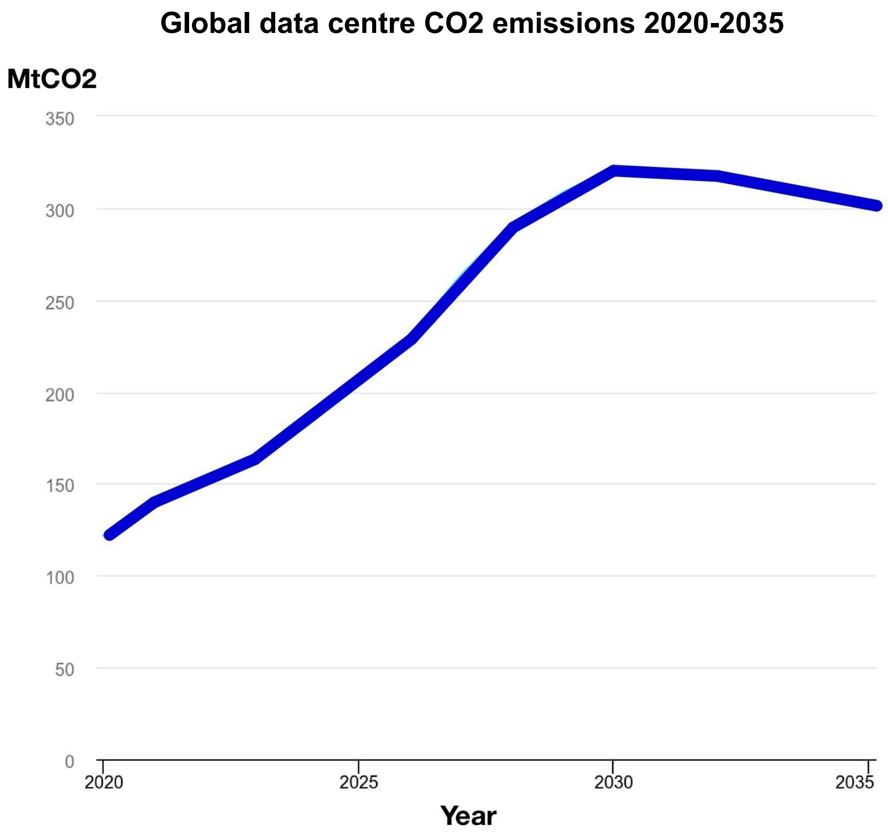
RQ3

Student: **Ana-Maria Muscă**
Main Supervisor: **Alexandru Iosup**
Daily Supervisor: **Dante Niewenhuis**

Datacenters Carbon Footprint Impact



Source: Data Age 2025 Sponsored by Seagate with data from IDC November 2018



IEA (2025), Global data centre CO2 emissions, Base Case, 2020-2035, IEA, Paris https://www.iea.org/data-and-statistics/charts/global-data-centre-co2-emissions-base-case-2020-2035, Licence: CC BY 4.0

MRQ: How to analyse the performance and carbon footprint of workloads in datacenters?

Conceptual & Technical Contributions

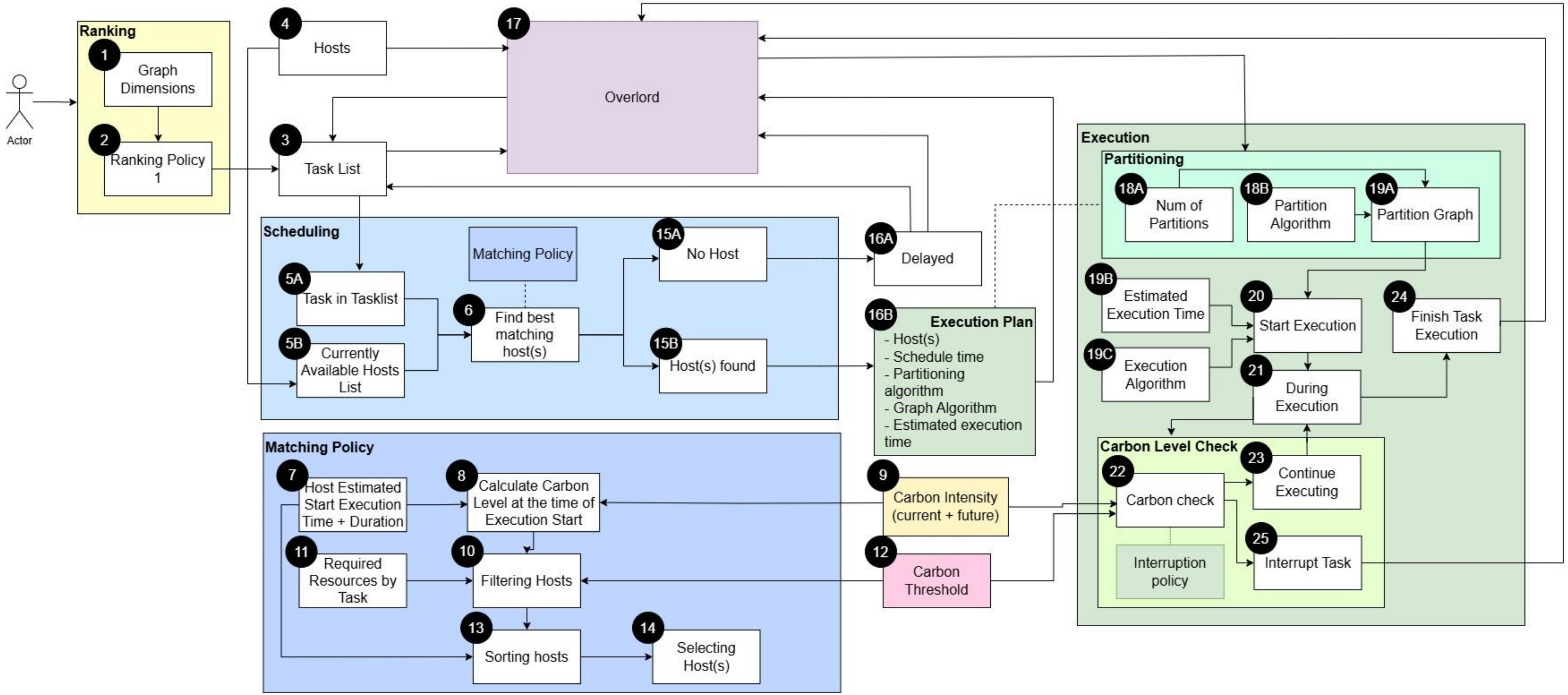
Conceptual Contributions:

1. Designed a serverless model with carbon emissions implementation for scheduling and execution of trivial and complex tasks.
2. Created a simplified model that is consistent with discrete event simulation principles.
3. An analysis of the performance-carbon intensity tradeoff in the context of Spatial shifting.
4. Combined Spatial shifting with task delays due shifting and failure model to show changes in carbon emissions.

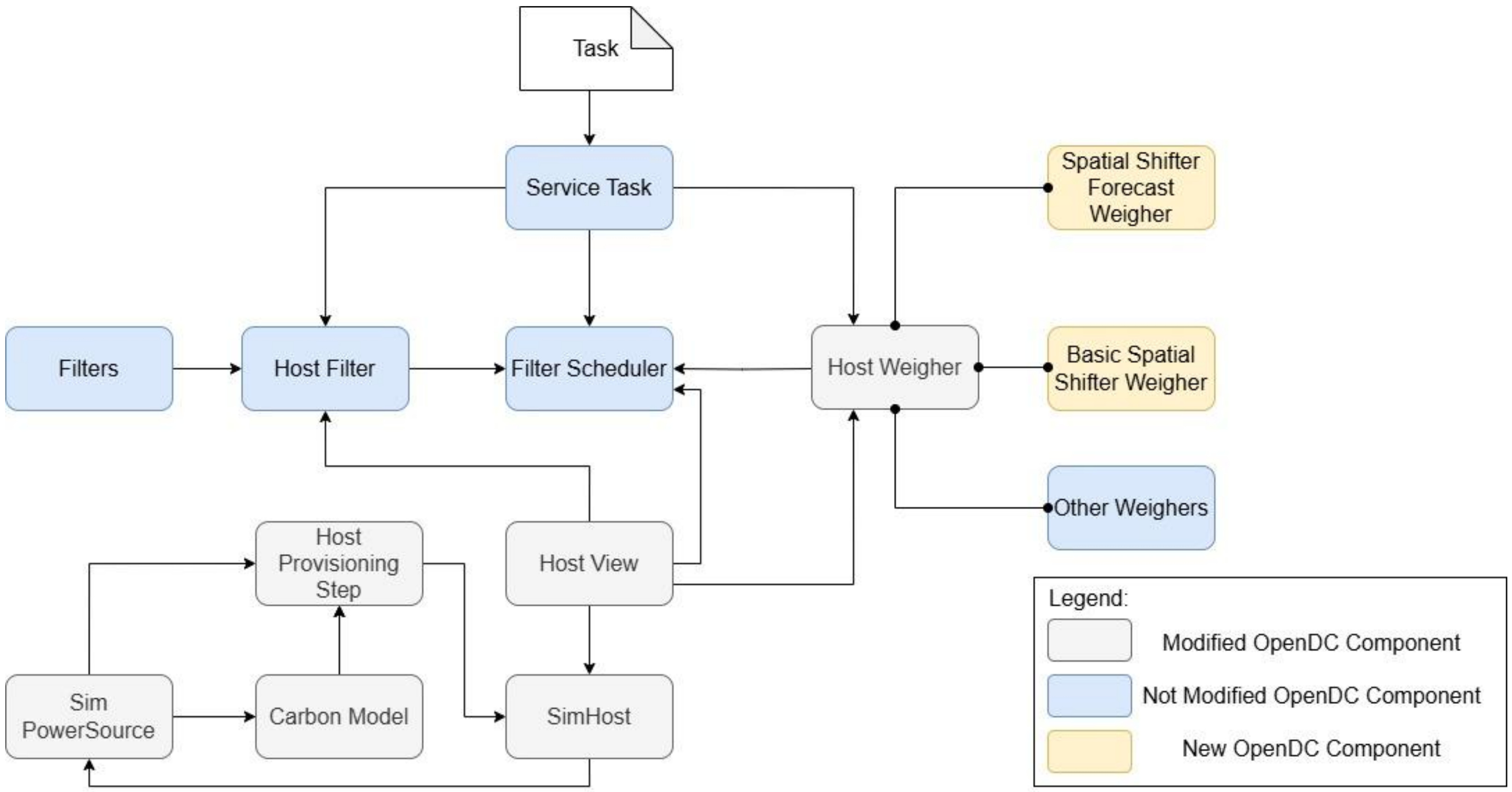
Technical Contributions:

1. Implementation of Spatial Shifting in a discrete event simulator, OpenDC.
2. The experiments with different levels of complexities.
3. The experimental setup considering cases with and without Spatial Shifting.

RQ1: How to model workloads running in datacenters using serverless models?



RQ2: How to simulate datacenters that use a serverless model for workload processing to optimize for performance and climate impact?

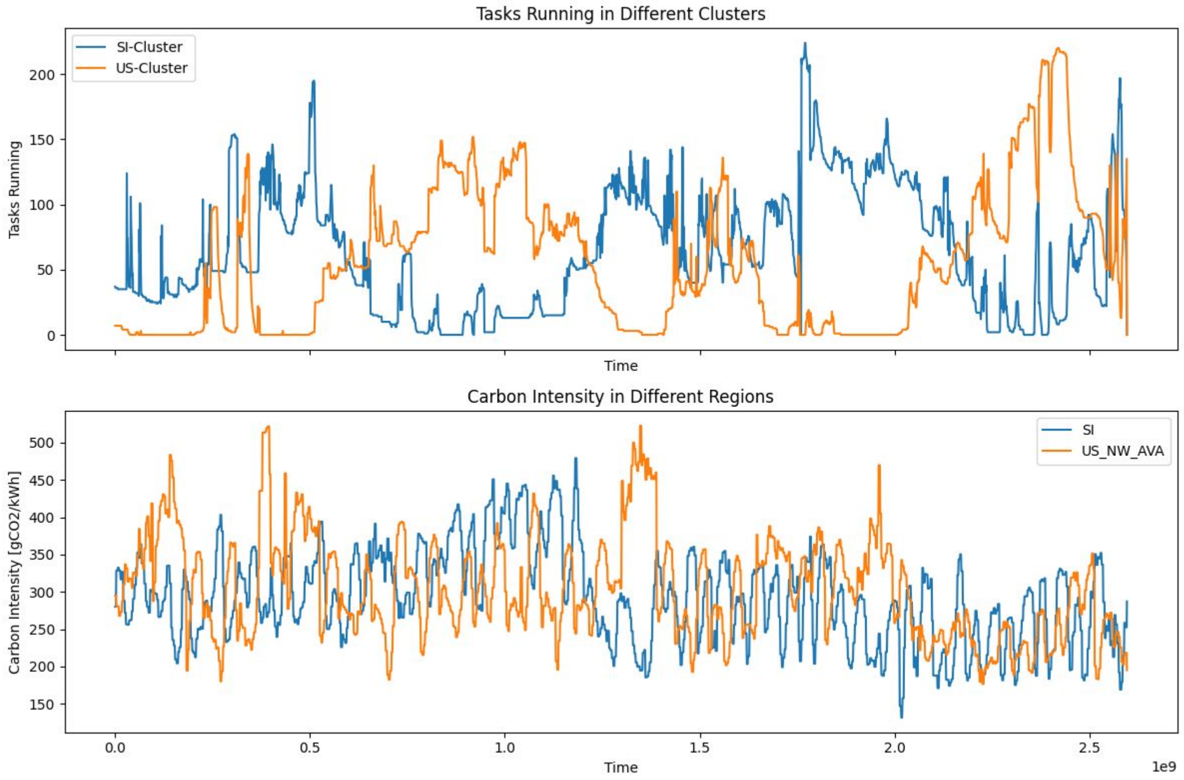


RQ3: What is the impact of datacenters using serverless models for workload processing, compared to non-serverless models for performance and climate impact?

Three complexity-level experiments:

1. **Simple Experiments:**
   a. Basic Spatial Shifting
   b. Spatial Shifting with Carbon Forecast
2. **Intermediate Experiment:**
   a. Spatial Shifting with Carbon Forecast and Transfer Costs
3. **Advanced Experiment:**
   a. Spatial Shifting with Carbon Forecast and Failure Model

Simple Experiments



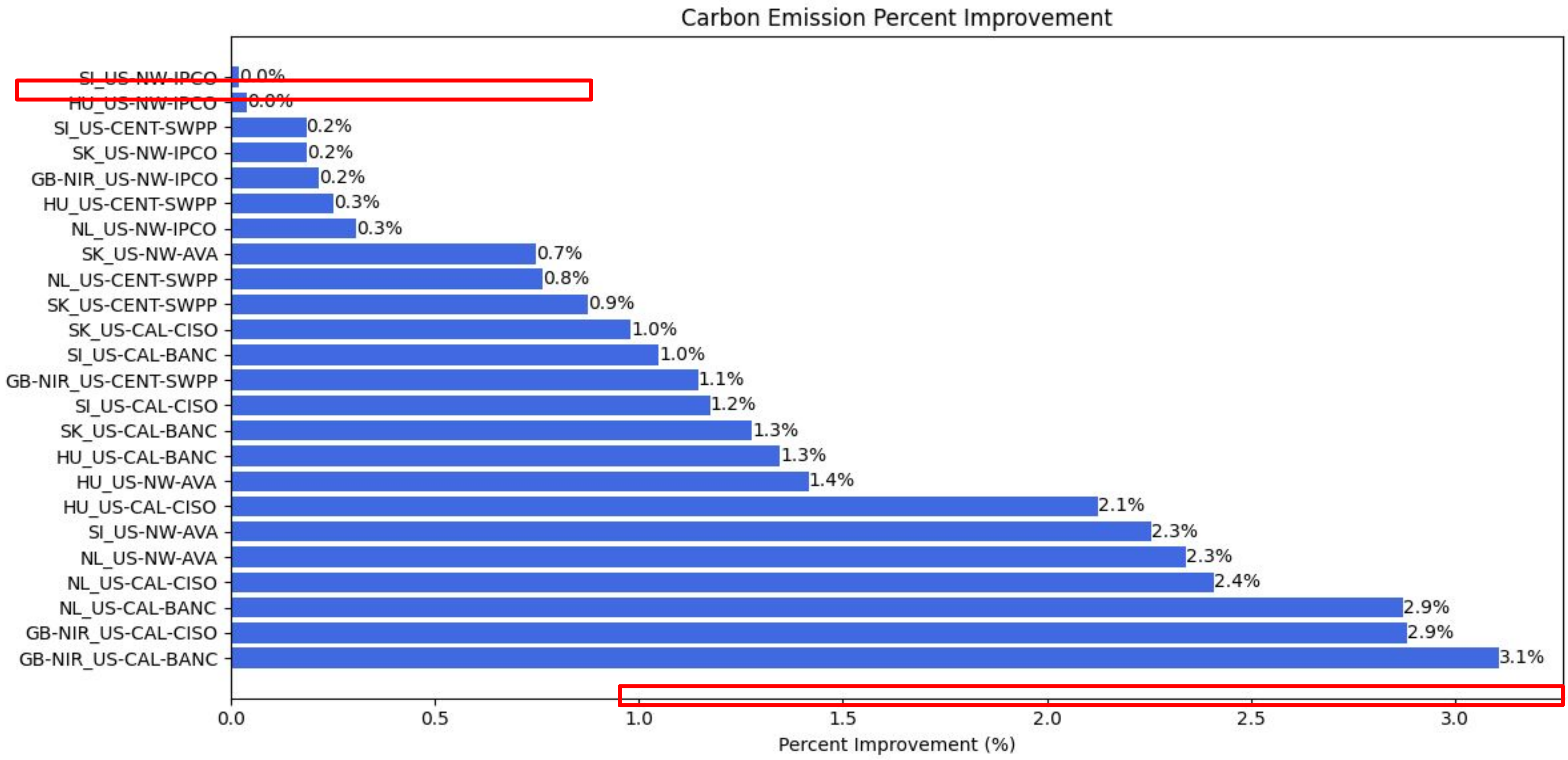
Basic Spatial Shifting

- Considered the carbon intensity at the time of the scheduling

Spatial Shifting with Carbon Forecast

- Considered the carbon intensity during the entire duration of the task

Experiment	CO2 Emissions in SI (kg)	CO2 Emissions in US_NW_AVA (kg)	CO2 Emissions if Spatial Shifting is Used (kg)
Basic Spatial Shifting	6691.97	6748.14	**6720.13**
Spatial Shifting with Forecast	6691.97	6748.14	**6541.09**

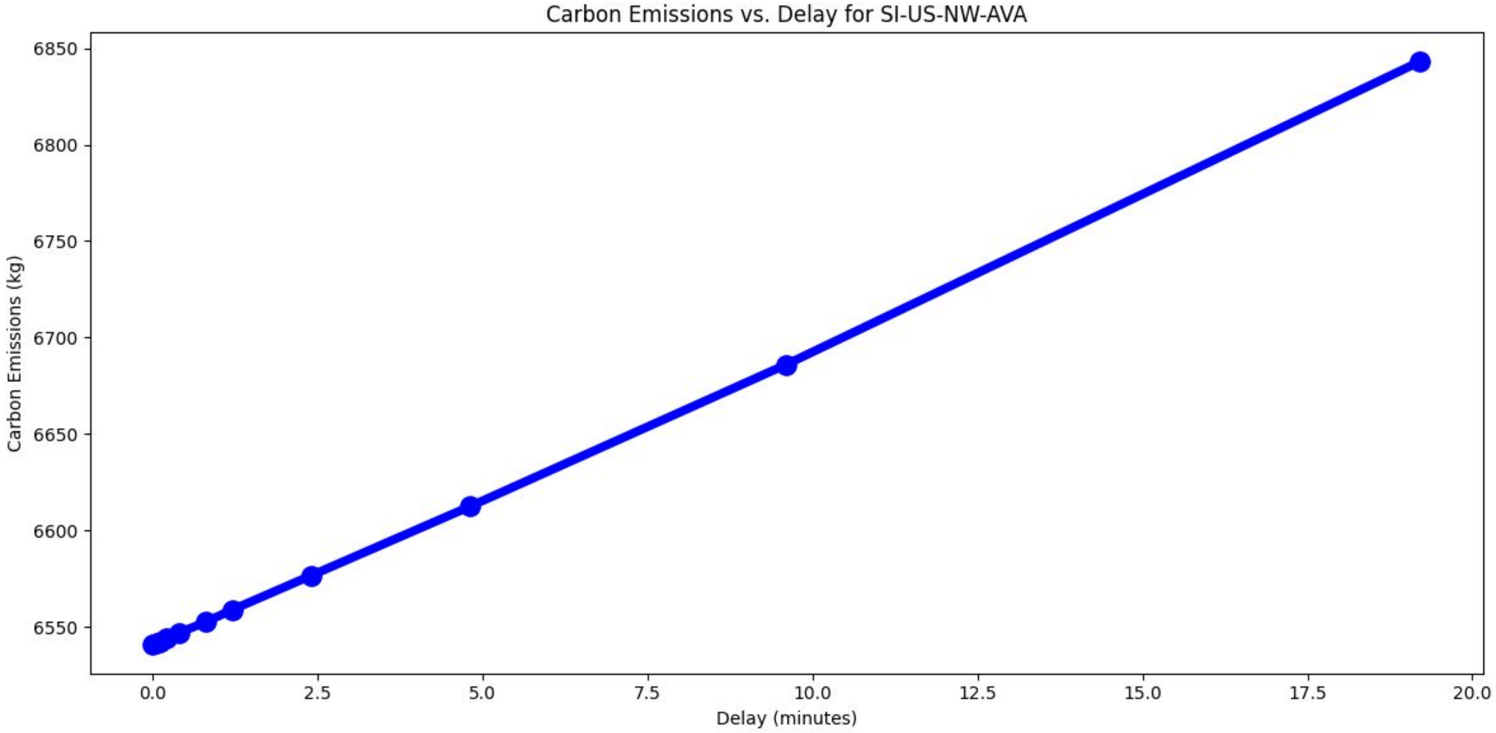

Carbon Emission Percent Improvement
SI_US-NW-IPCO
HU_US-NW-IPCO
SI_US-CENT-SWPP
SK_US-NW-IPCO
GB-NIR_US-NW-IPCO
HU_US-CENT-SWPP
NL_US-NW-IPCO
SK_US-NW-AVA
NL_US-CENT-SWPP
SK_US-CENT-SWPP
SK_US-CAL-CISO
SI_US-CAL-BANC
GB-NIR_US-CENT-SWPP
SI_US-CAL-CISO
SK_US-CAL-BANC
HU_US-CAL-BANC
HU_US-NW-AVA
HU_US-CAL-CISO
SI_US-NW-AVA
NL_US-NW-AVA
NL_US-CAL-CISO
NL_US-CAL-BANC
GB-NIR_US-CAL-CISO
GB-NIR_US-CAL-BANC
0.0%
0.0%
0.2%
0.2%
0.2%
0.3%
0.3%
0.7%
0.8%
0.9%
1.0%
1.0%
1.1%
1.2%
1.3%
1.3%
1.4%
2.1%
2.3%
2.3%
2.4%
2.9%
2.9%
3.1%
0.0
0.5
1.0
1.5
2.0
2.5
3.0
Percent Improvement (%)

Intermediate Experiment

Spatial Shifting with Carbon Forecast and Transfer Cost

1. Moving a task from one datacenter to another will generate costs in real-world scenarios.
2. We sum up the transfer costs by delaying the task.
3. Delaying a task = adding a fragment to the task with a certain duration
4. Different delays for short and long tasks

Observation: If transfer costs are high, spatial shifting does not bring improvements.



Advanced Experiment

Spatial Shifting with Carbon Forecast and Failure Model

Failure Model: if a host has a failure, all the tasks running on the host get interrupted and nothing can be scheduled until the host is fixed again.

Different reliabilities of datacenters might affect the spatial shifting.

Metric	Datatype	Unit	Summary
failure_interval	int64	milli seconds	The duration since the last failure
failure_duration	int64	milli seconds	The duration of the failure
failure_intensity	float64	ratio	The ratio of hosts effected by the failure

Conclusion and Further Work

Conclusion:

Spatial shifting can lead to improvements regarding carbon emissions, but

Limitations:

1. Moving a task from one datacenter to another might be costly.
2. A datacenter with overall better carbon intensities might be overloaded resulting in tasks being delayed for a long time.
3. Some tasks might be not allowed to be moved due to different regulations (e.g., privacy laws).

Future Work:

1. Analyse the benefits of spatial shifting in combination with temporal.
2. A more in-depth exploration of the current limitations.

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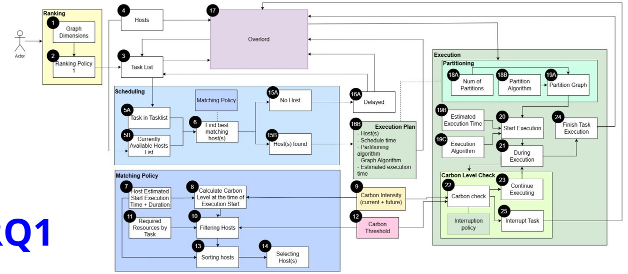
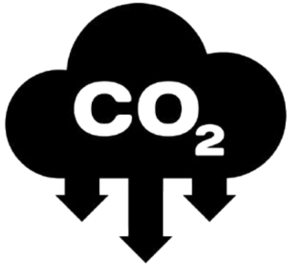
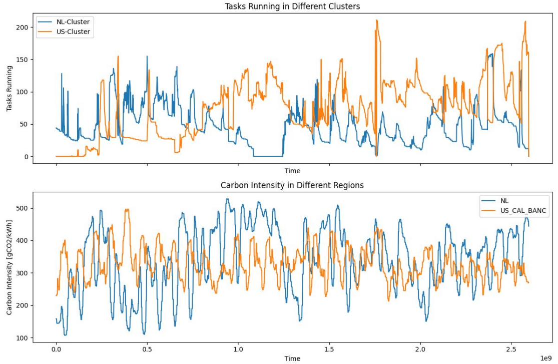


RQ1



RQ2

RQ3



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@Large Research
Massivizing Computer Systems

Thank you!

VU Vrije Universiteit Amsterdam