GreenCourier: Carbon-aware Scheduling for Serverless Functions

9th International Workshop on Serverless Computing (WoSC9)
In conjunction with, ACM/IFIP Middleware 2023

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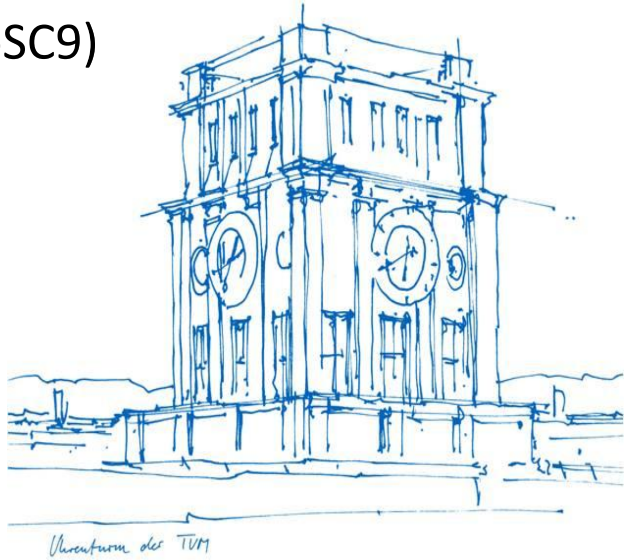

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Research Areas:

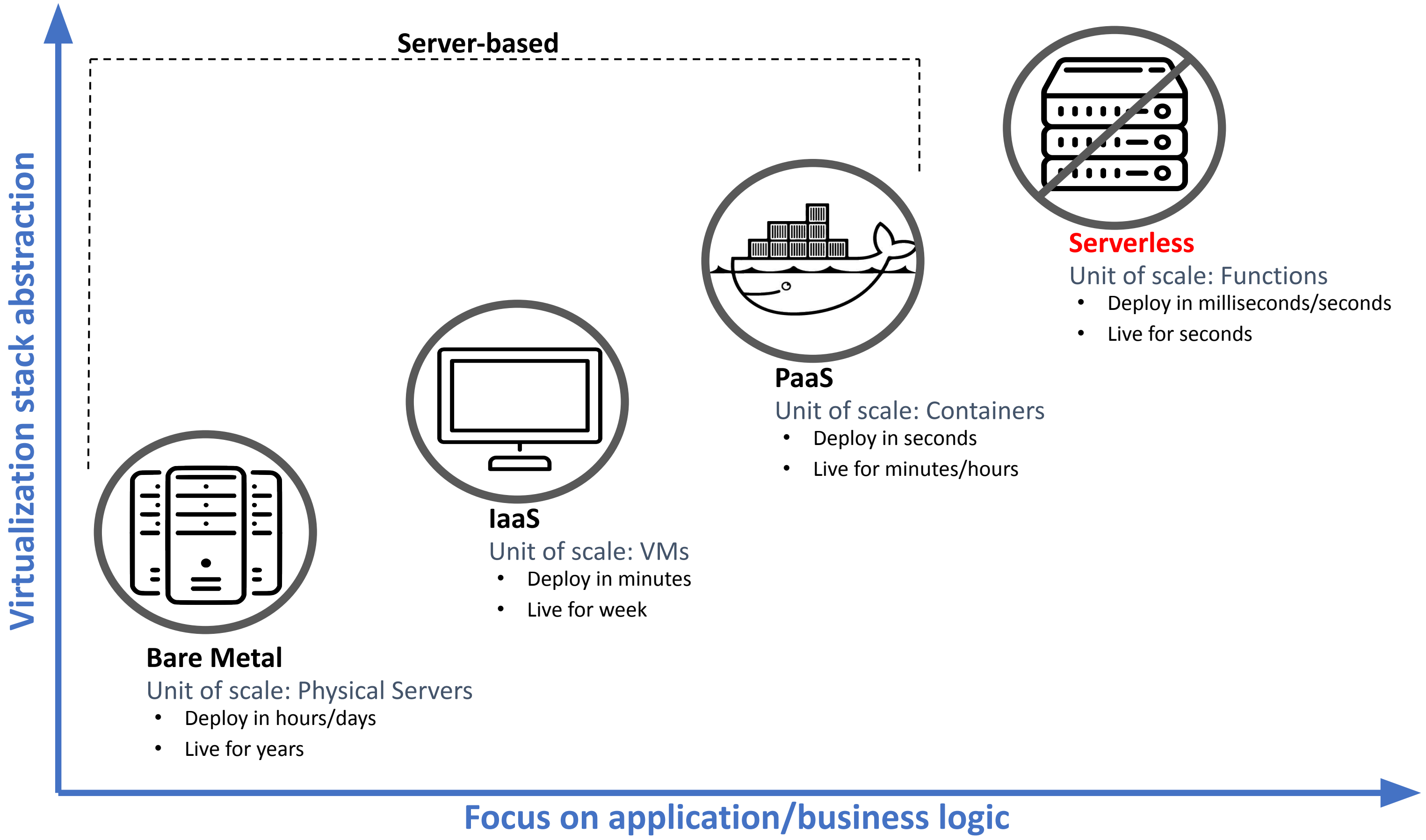
High Performance Computing
Cloud Computing
Quantum Computing
Edge Computing

- **Recent Publications:**
  - ASPLOS'23, PPoPP'23, CLUSTER'23, Middleware'23, ICPP'23, ICCD'23, CCGrid'23, ISC'23…

Outline

1. Serverless Computing
2. Challenges in Sustainable Serverless Computing
3. **GreenCourier**
4. Evaluation
5. Conclusion

Serverless Computing



Function-as-a-Service Platforms

AWS Lambda

Azure Functions

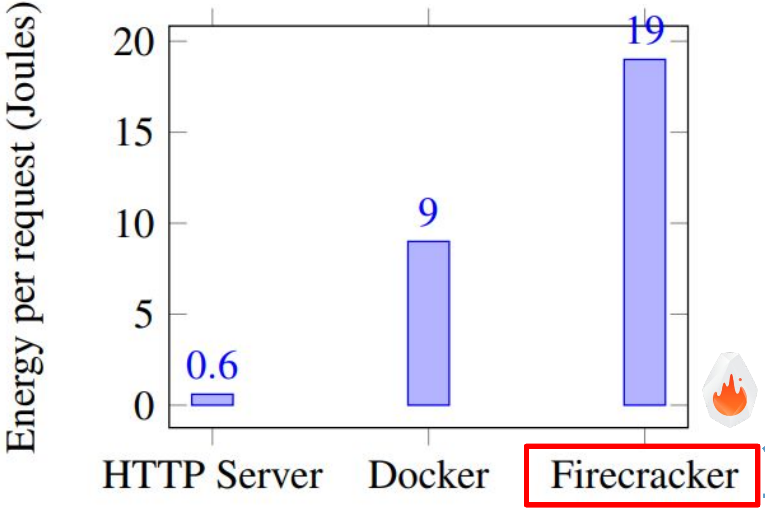
1.1 Billion Function Invocations each day [ATC'19, SOSP'21]

Google Cloud Functions

IBM Cloud Functions

Challenges in Sustainable Serverless Computing

① **FaaS virtualization overheads can increase the energy consumption by more than 15x compared to conventional HTTP servers. [HotCarbon'22]**



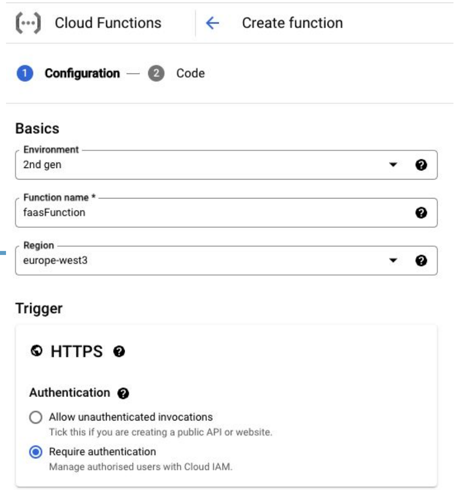
AWS Lambda

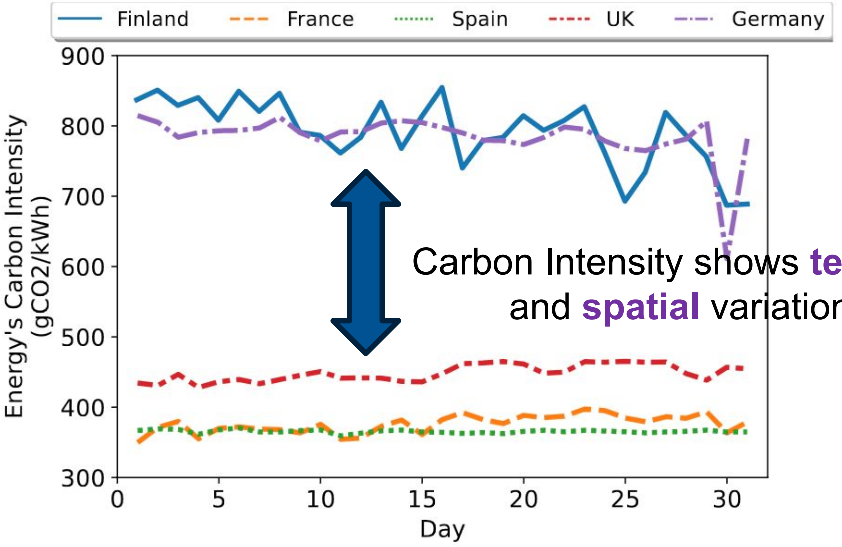
AWS Fargate

Challenges in Sustainable Serverless Computing

② **Pre-selection** **of the geographical region (datacenter) for function execution during function deployment.**

Frankfurt, Germany





Carbon Intensity shows **temporal** and **spatial** variations

GreenCourier

GreenCourier optimises the delivery of serverless functions across geo-spatial multi-cluster environment in the cloud for carbon efficiency.

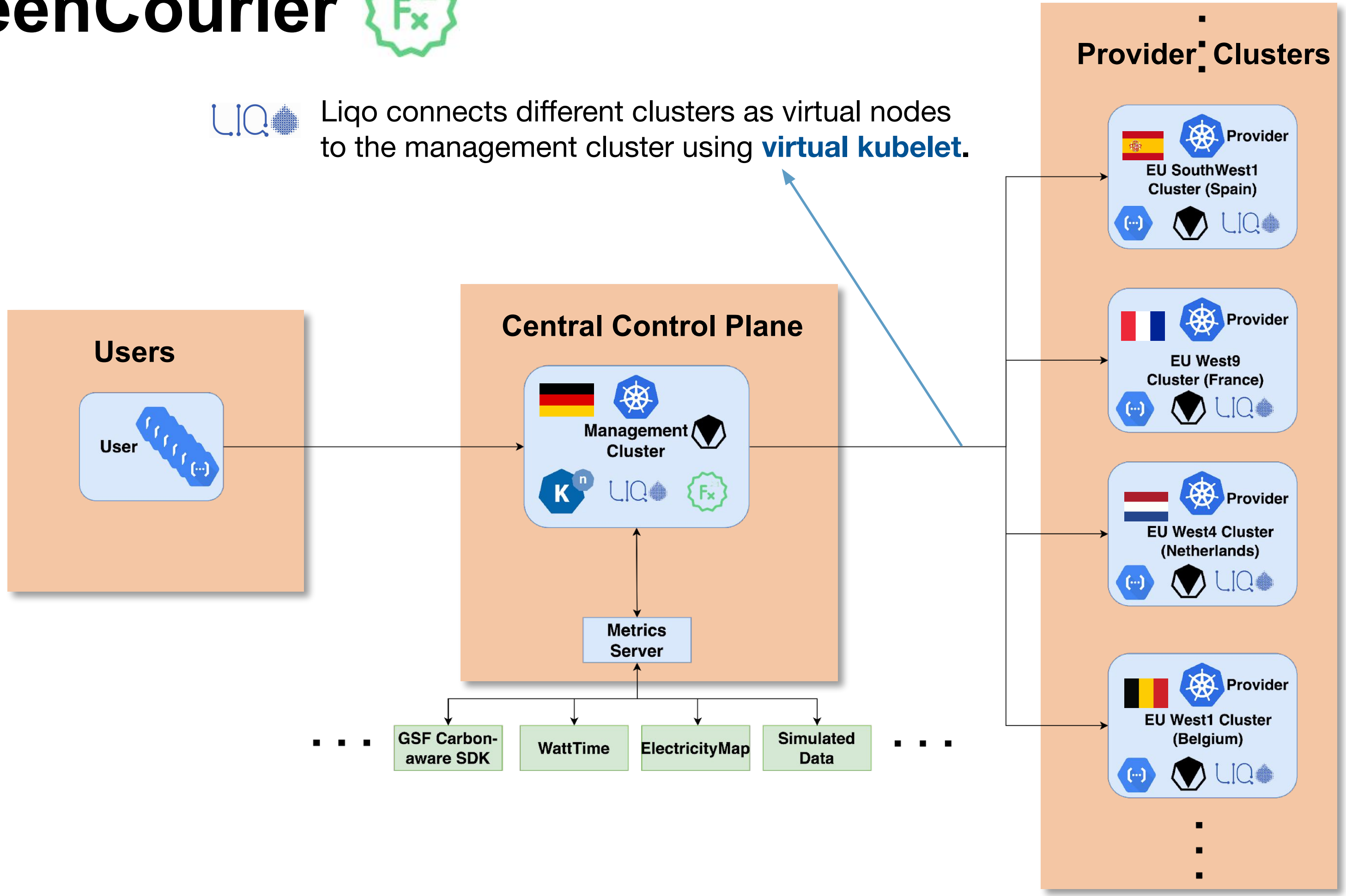
GreenCourier builds on Kubernetes and Knative.

Defacto platform for container orchestration
(offered by Microsoft, Amazon, Google, …)

Enterprise-level platform to build serverless applications
(used by Google, IBM, …)

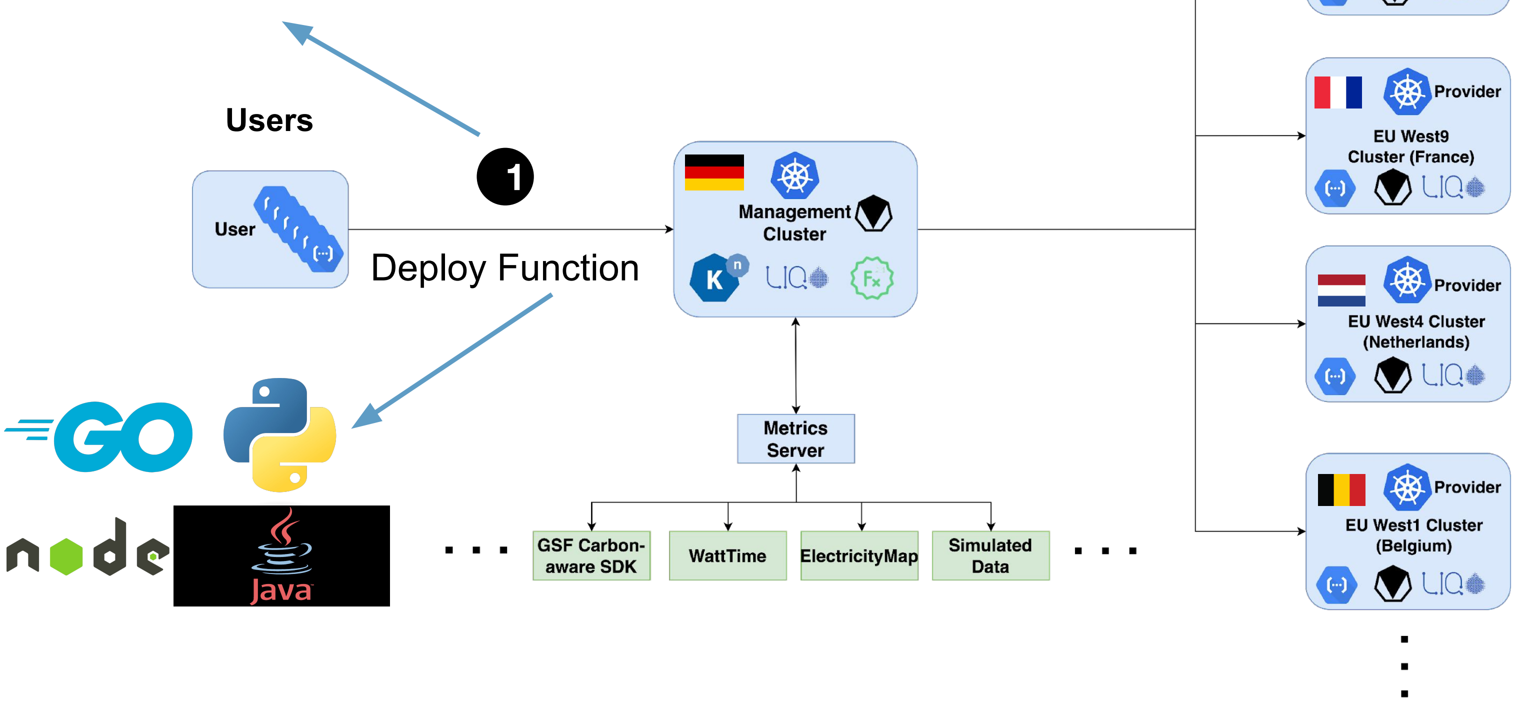
GreenCourier

Liqo connects different clusters as virtual nodes to the management cluster using **virtual kubelet.**

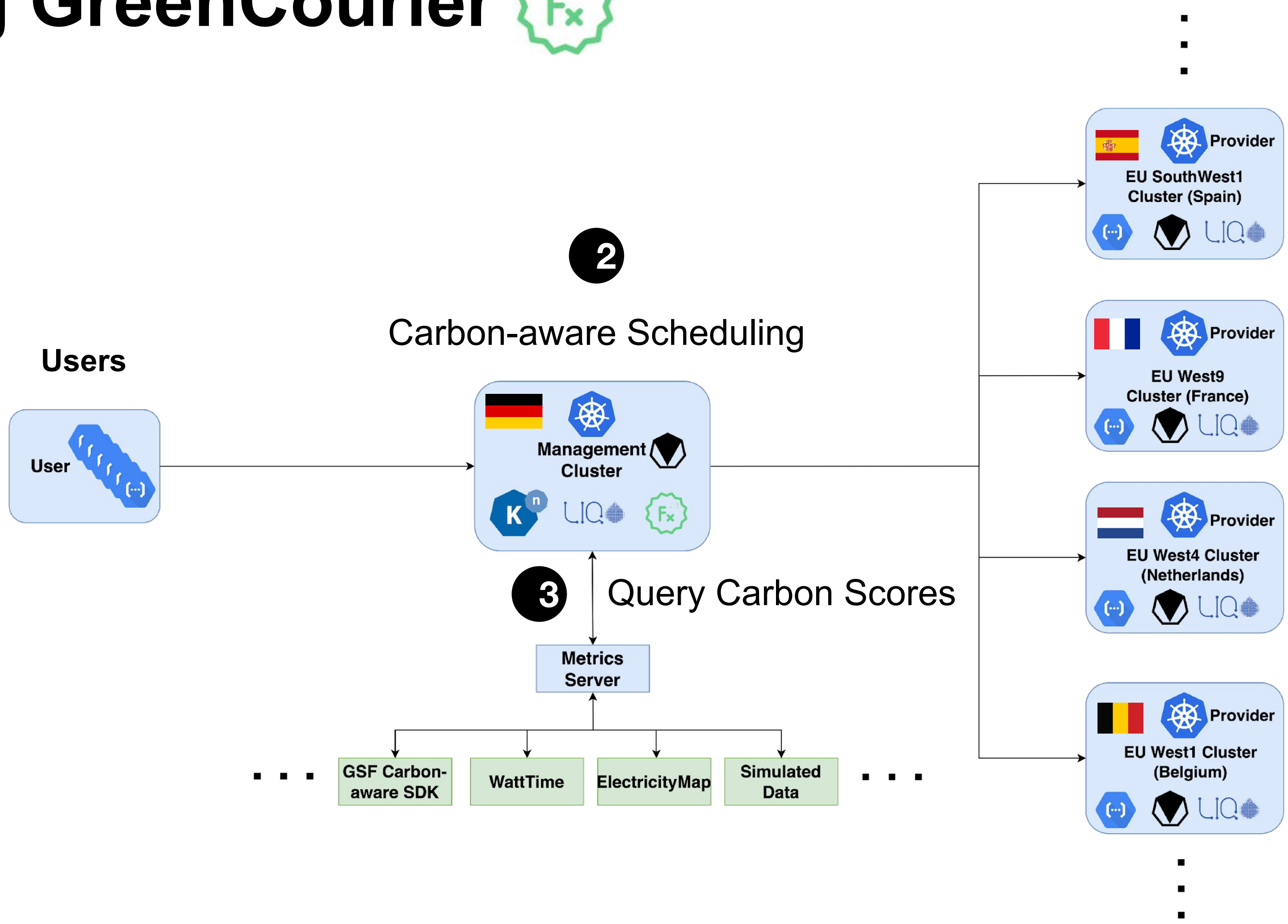


Using GreenCourier

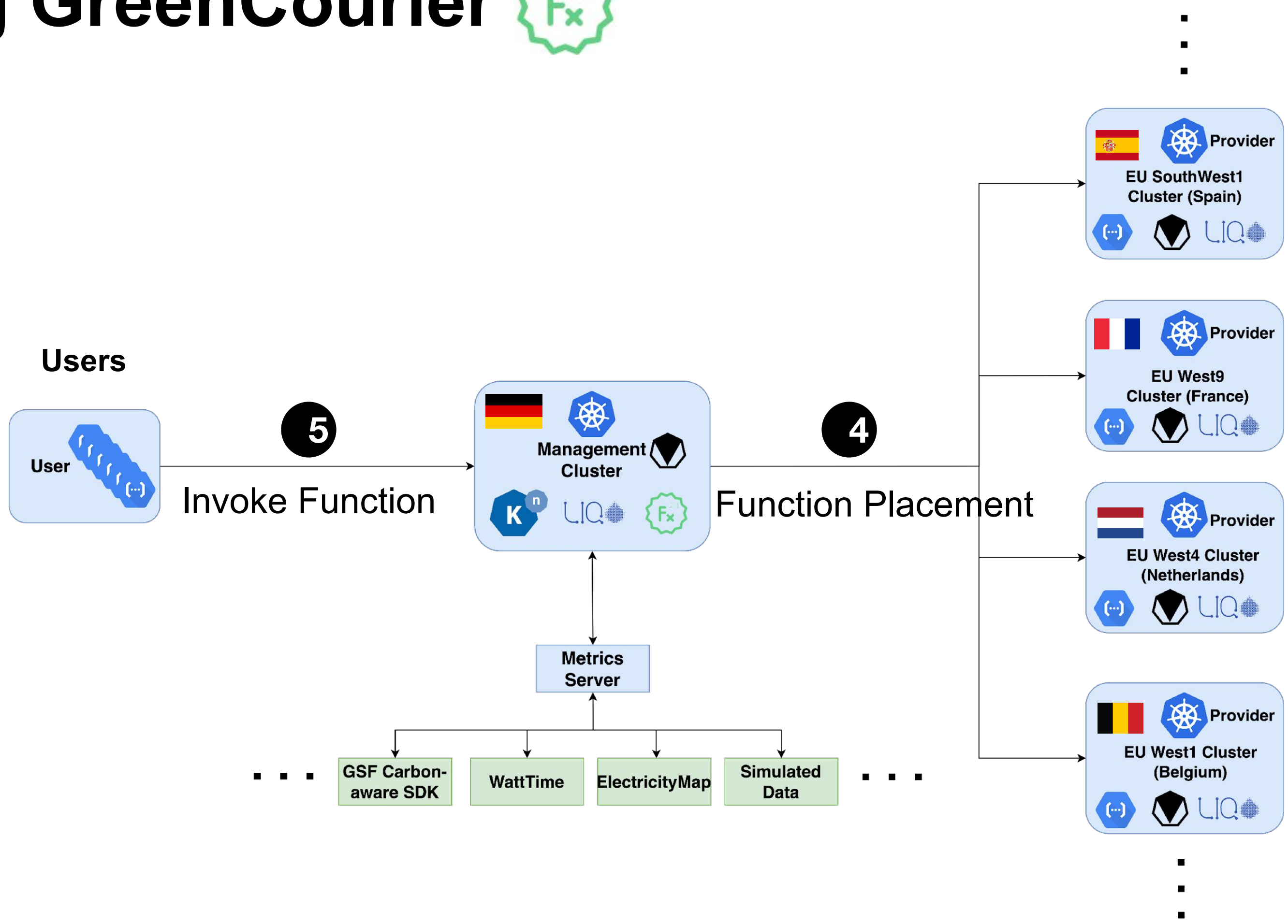
schedulerName: kube-carbon-scheduler



Using GreenCourier



Using GreenCourier



Experimental Evaluation

- All experiments on Google Kubernetes Engine.
- Eight standardized serverless functions [CLOUD'19].
- Function request pattern using production function traces.
- Comparison with

GreenCourier

Default

GeoAware

Metrics

- ❑ Carbon emissions
- ❑ Function Response Times
- ❑ Scheduling Latency
- ❑ Binding Latency

Quantifying Carbon Emissions

Software Carbon Intensity (SCI) Specification

Green Software Foundation

$$SCI = ((E * I) + M)/R$$

Energy consumption of software.

Marginal emissions factor.

Embodied emissions.

Functional unit.

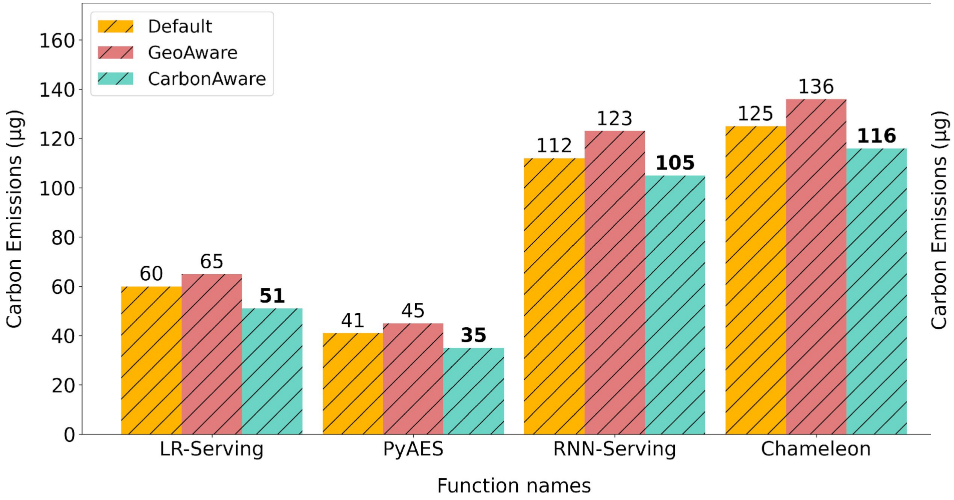
More Info:

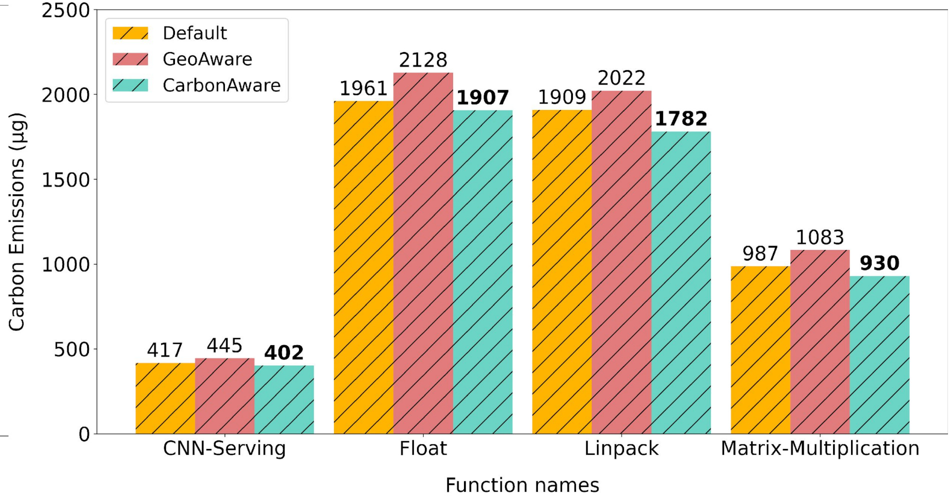
Comparing Carbon Emissions

8.7% vs Default

17.8% vs GeoAware

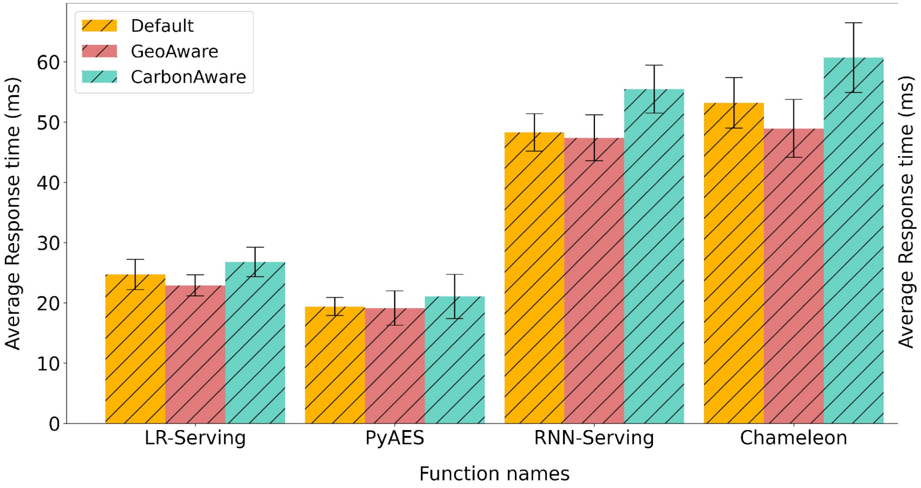
per function invocation



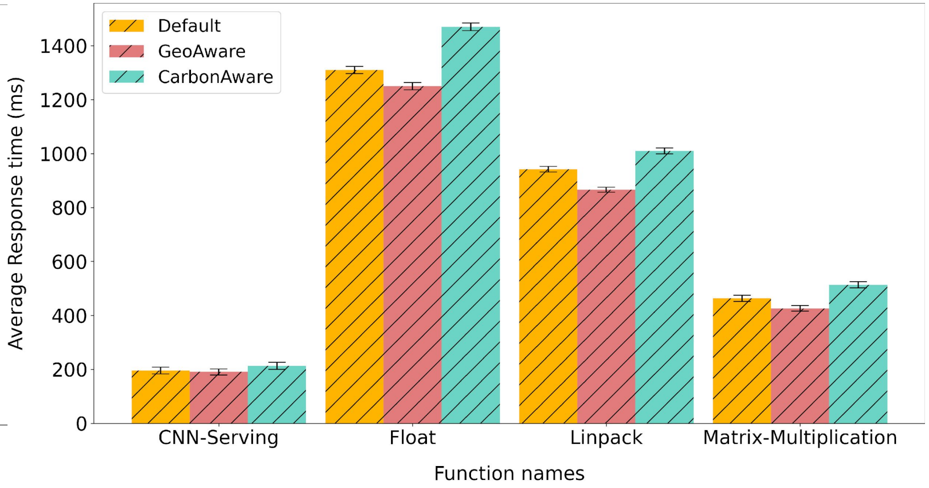


Comparing Response Times

10.26% vs Default



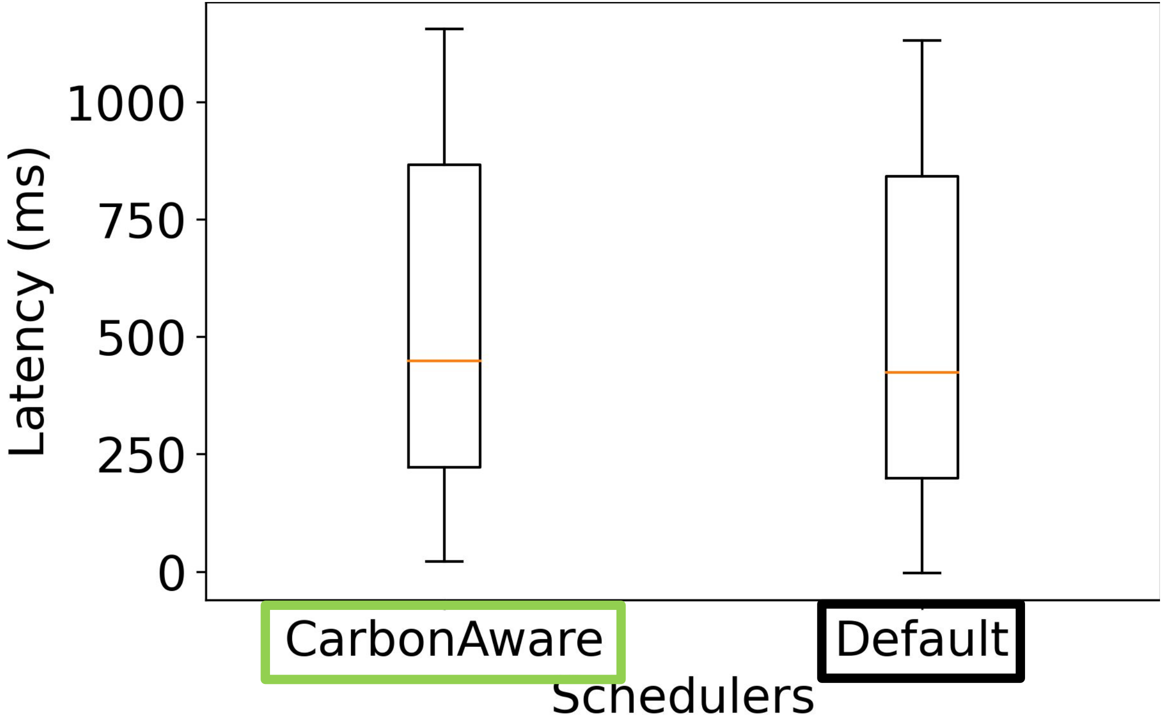
16.24% vs GeoAware



Scheduling Latency

GreenCourier: 539 ms/pod

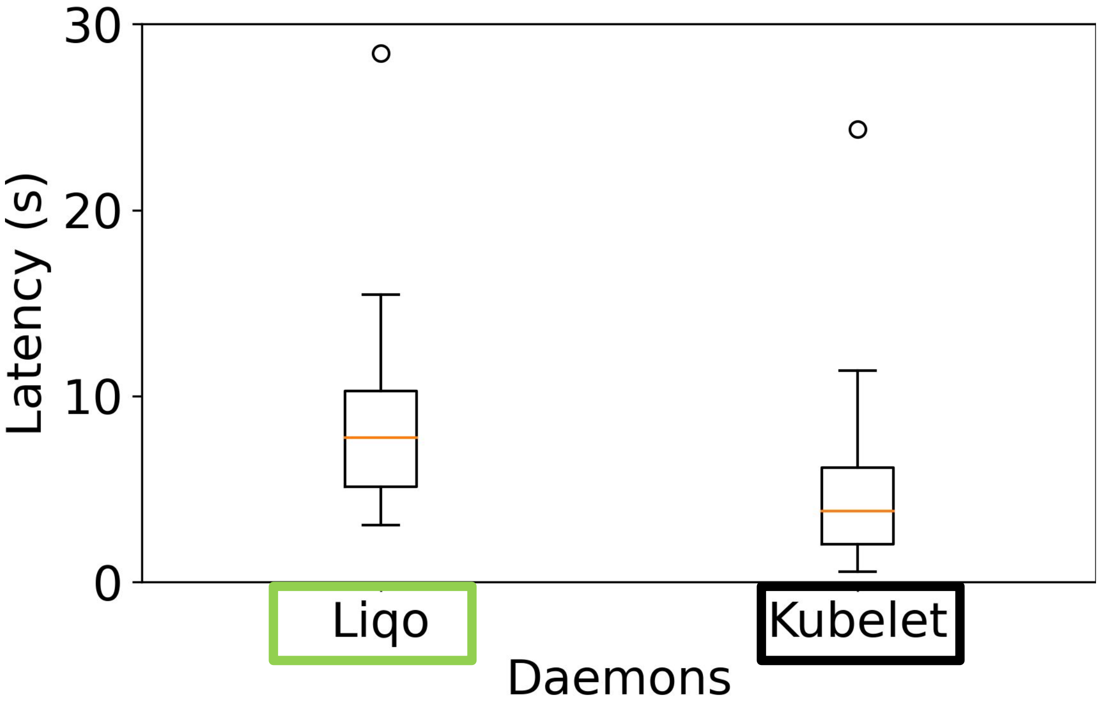
Default: 515 ms/pod



Binding Latency

GreenCourier: 8.28 sec/pod

Default: 4.53 sec/pod



Future Work

Adding **HA** Capability.

Enhancement of **NAT** scheme at the level of Liqo.

Improve **status synchronization** performance at the level of Liqo.

Thank You

Key Takeaways:

- GreenCourier enables **carbon-aware** scheduling of serverless functions at runtime across **geographically** distributed clusters.
- Native support for Kubernetes and Knative.
- Easy to use.
- GreenCourier can significantly **reduce** runtime **carbon emissions.**

GreenCourier:

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Backup Slides

Carbon Emissions

Energy

To calculate the energy consumed by a machine, you need to calculate the power consumption of the CPUs, GPUs, and Memory. To simplify this scenario, I am going to use an Azure VM type of D8as v4. According to the Azure documentation, this VM type uses an AMD EPYC 7452 processor which is specified as having 155W thermal design power (TDP). Running this processor at 50% load for 24 hours consumes 1,860 watts hours, or 1.86 kWh (TDP * Load * Hours). The D8as v4 virtual machine has 1 CPU, no GPU processors, and 32 GB of memory. As a rule of thumb, 8GB of RAM consumes about 3W of power so the memory power consumption would be 12W. In this scenario we can ignore the GPU requirements as the D8as v4 machine does not have GPUs. Now we can multiply our CPU energy consumption by the number of CPUs (1) to get 1.86kWh

1.87kWh = (1 CPUs * 1.86 kWh) + 12 W memory power + (0 GPU cores * 0 GPU power)

Marginal vs Average

Marginal - The additional emissions are not distributed evenly amongst its users but are instead directed to the one who caused such a reduction
Average - The footprint of your electricity is the same as other users on the grid. Because benefits are distributed across all grid users, your *claimable* benefits will be limited.