A K8s-based Workload Allocation Optimizer for Minimizing Power Consumption

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Outline

- Who are we
- Background
  - Challenge of Power consumption on Cloud-Edge computing system
- Our proposed solution: K8s-based Workload Allocation Optimizer (WAO)
  - WAO scheduler
  - WAO load balancer (WAOLB)
- Performance evaluation
  - What is the WAO's performance?
  - How much data center power reduction can be obtained by using WAO?
  - Evaluation of WAO based scheduler and WAO based load balancer
- Conclusion

Who are we: *Matsuoka Lab at Osaka Univ.*

Osaka
DC_1

~ 350 servers

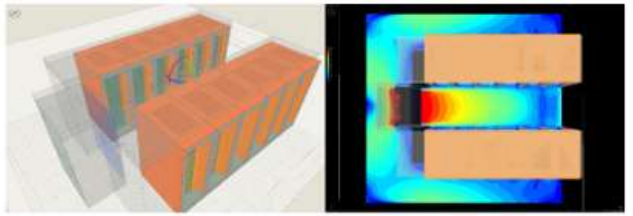
Osaka
DC_2

~ 350 servers

Detailed power consumption related data

ML Power Consumption
Model (each server)

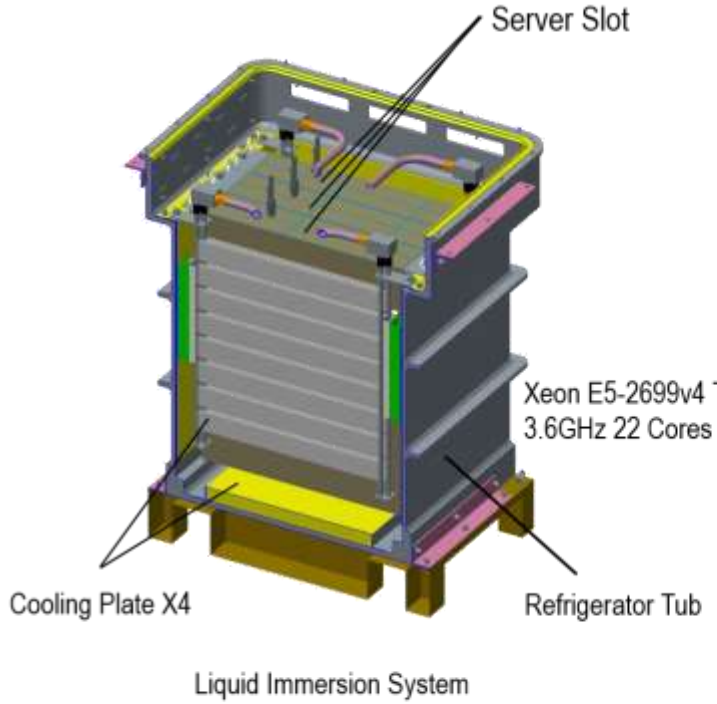
+

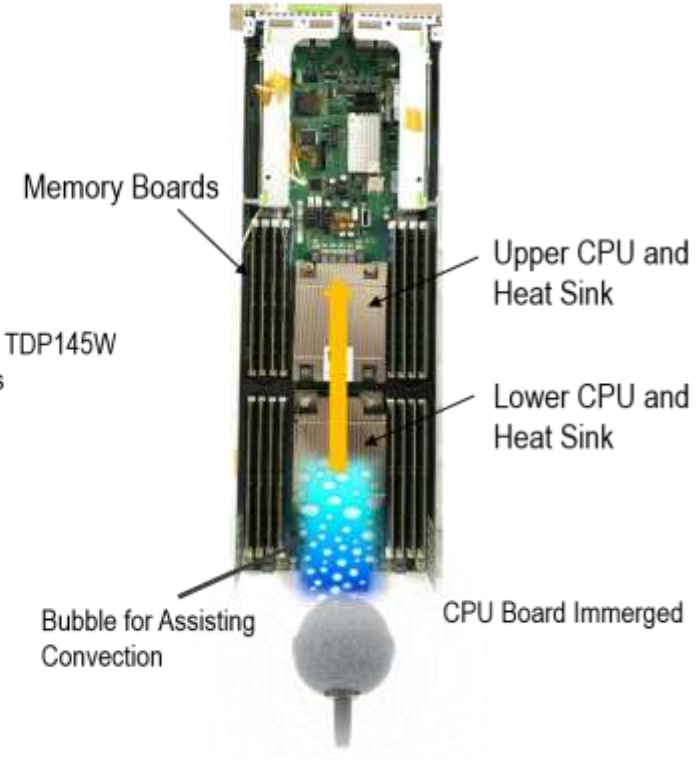


CFD

Power consumption Models

Our technology: Liquid immersion cooling

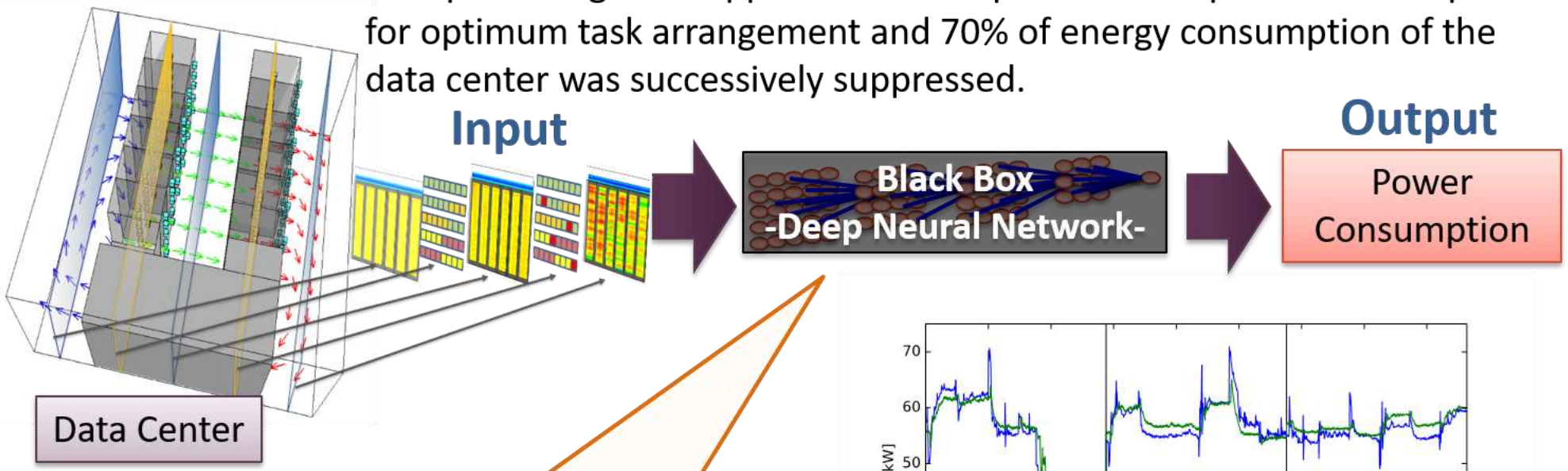


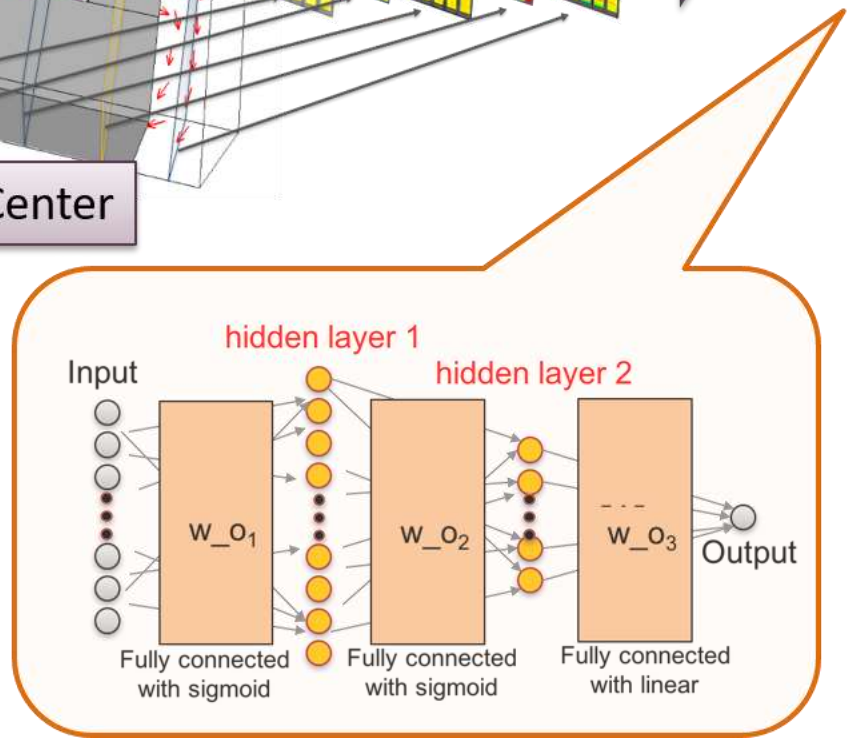


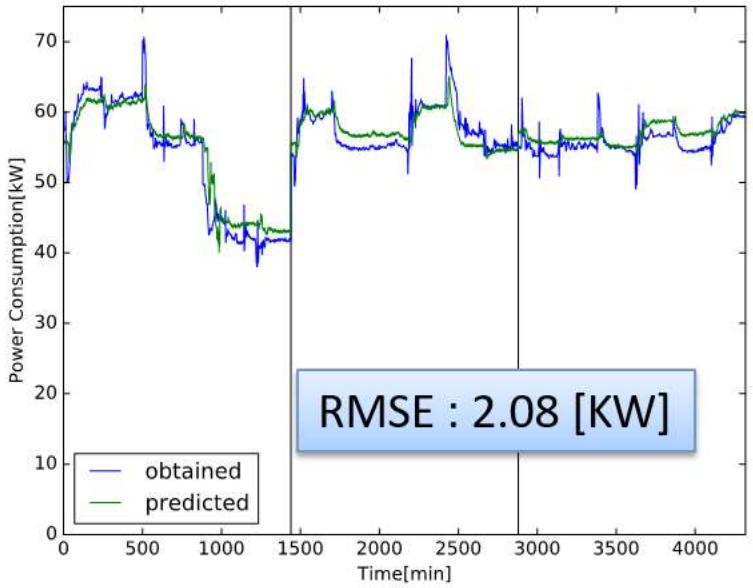
* **Liquid immersion cooling** technology with natural convection in data center
Morito Matsuoka, Kazuhiro Matsuda, Hideo Kubo (IEEE CloudNet 2017)
* Proposal of **liquid immersion cooling** with bubble-assisted natural convection for HPC-based cloud computing system Morito Matsuoka, Kazuhiro Matsuda, Hideo Kubo (opencompute.org)

Our technology: optimal task allocation

"Deep learning" was applied for direct prediction of power consumption for optimum task arrangement and 70% of energy consumption of the data center was successively suppressed.







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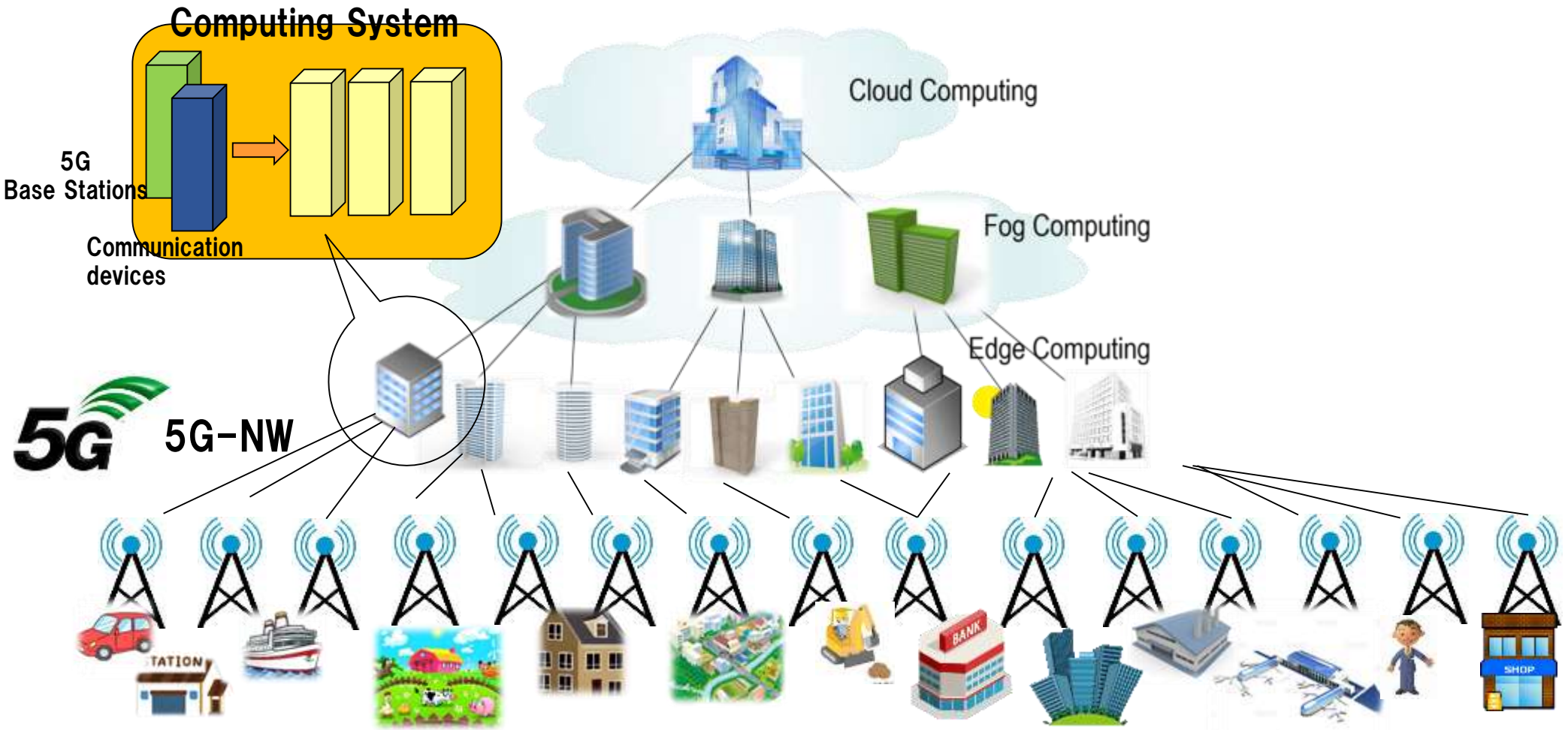
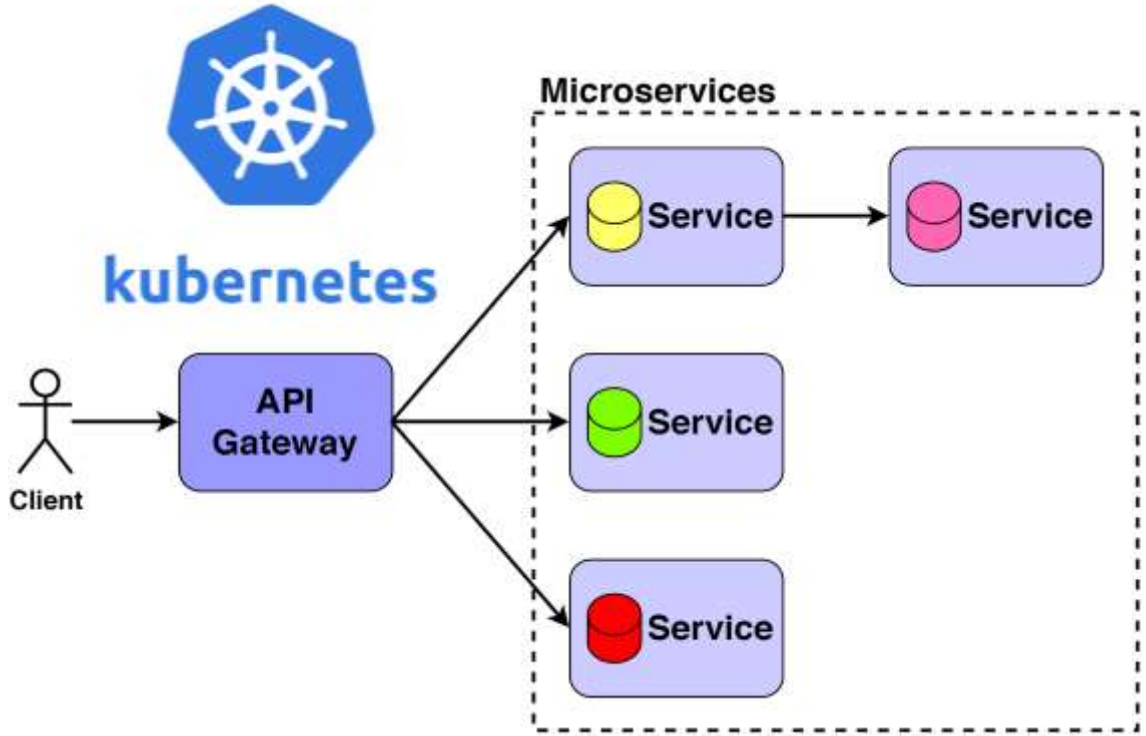
The complexity of edge computing systems



Spread of Microservices & Power consumption increases

Significant increase in cloud edge systems used to provide microservices

- K8s provides complex container management
- Solution of increasing in power consumption?



power consumption increase

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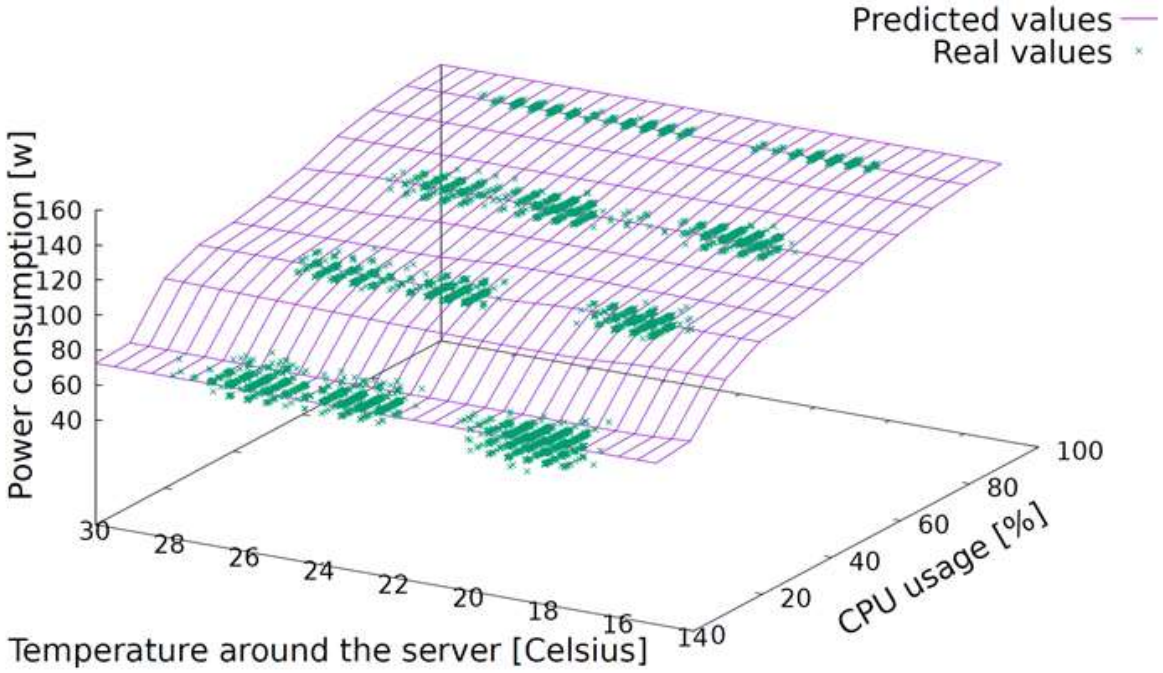
Our Approach: WAO

Workload Allocation Optimizer (WAO)

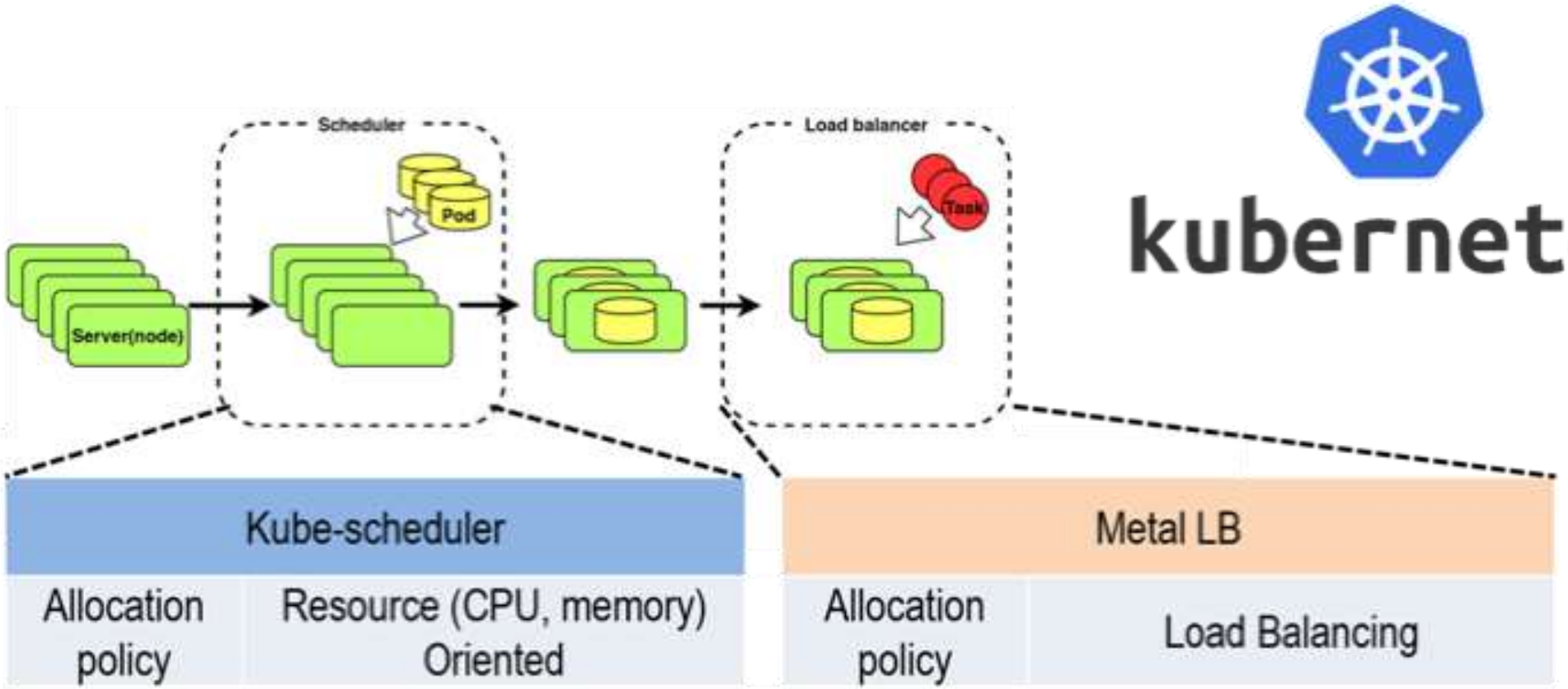
- Allocate tasks using power consumption prediction



Making the power consumption prediction using machine learning

Our Approach: WAO on K8s

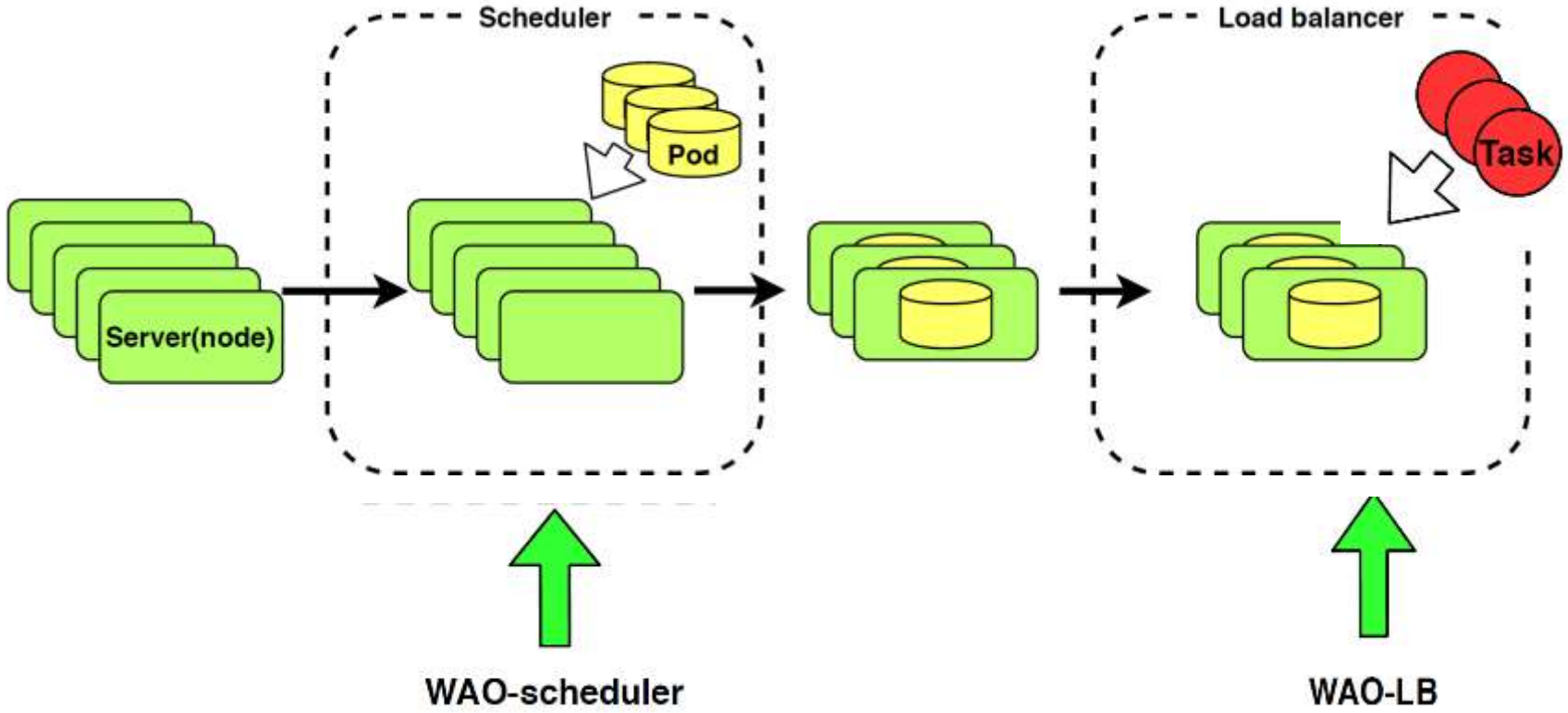
Pod : smallest deployable unit and consist of single or multiple containers
Node : either virtual or physical machines



Our Approach

Employing WAO for power consumption reduction through the K8s platform

- Pod allocation: WAO based scheduler (WAO-scheduler)
- Task allocation: WAO based load balancer (WAO-LB)



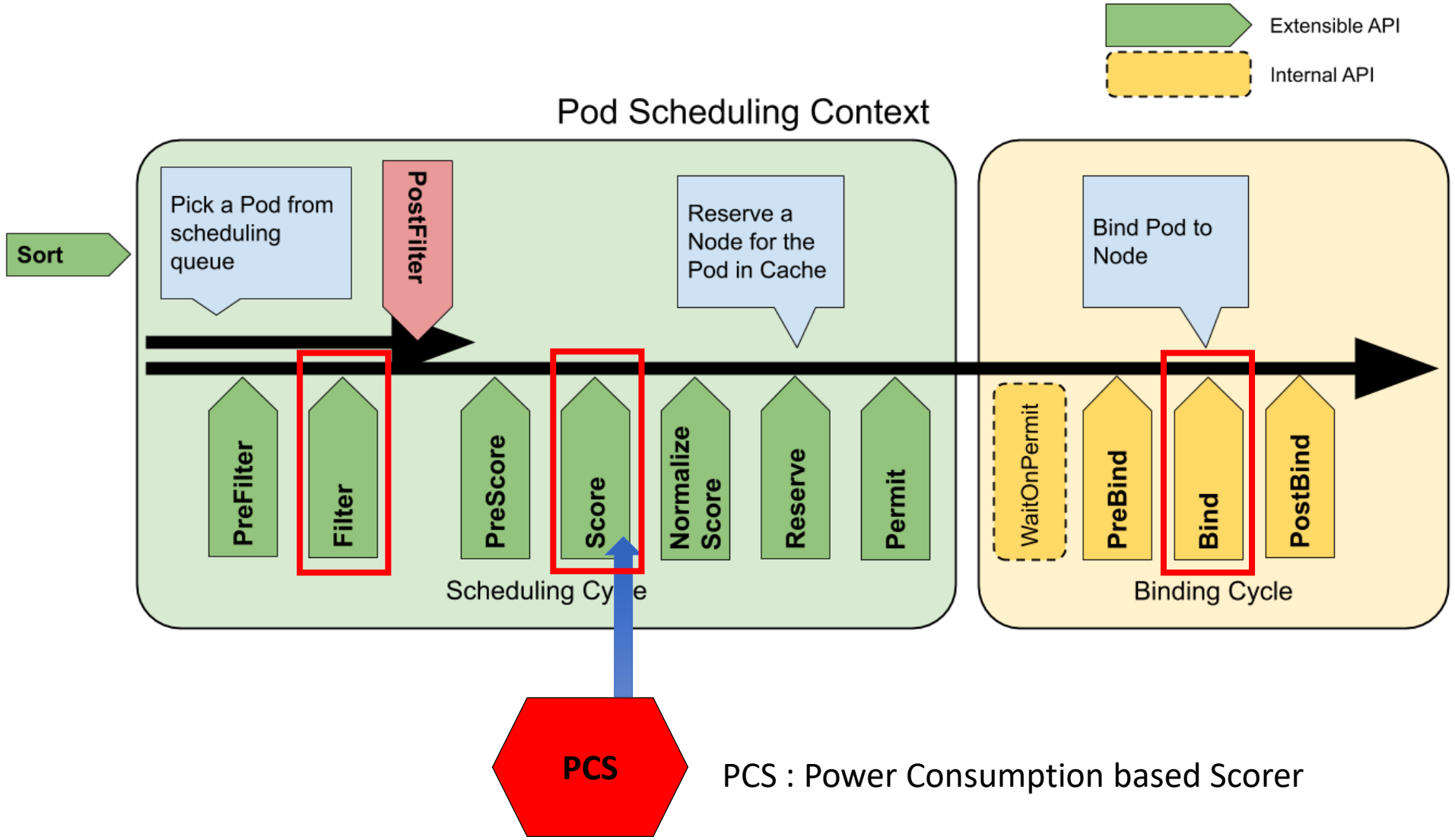
kubernetes

WAO power saving operation strategy

Kube-scheduler	WAO-scheduler
Resource (CPU, memory) Oriented	Power consumption priority control

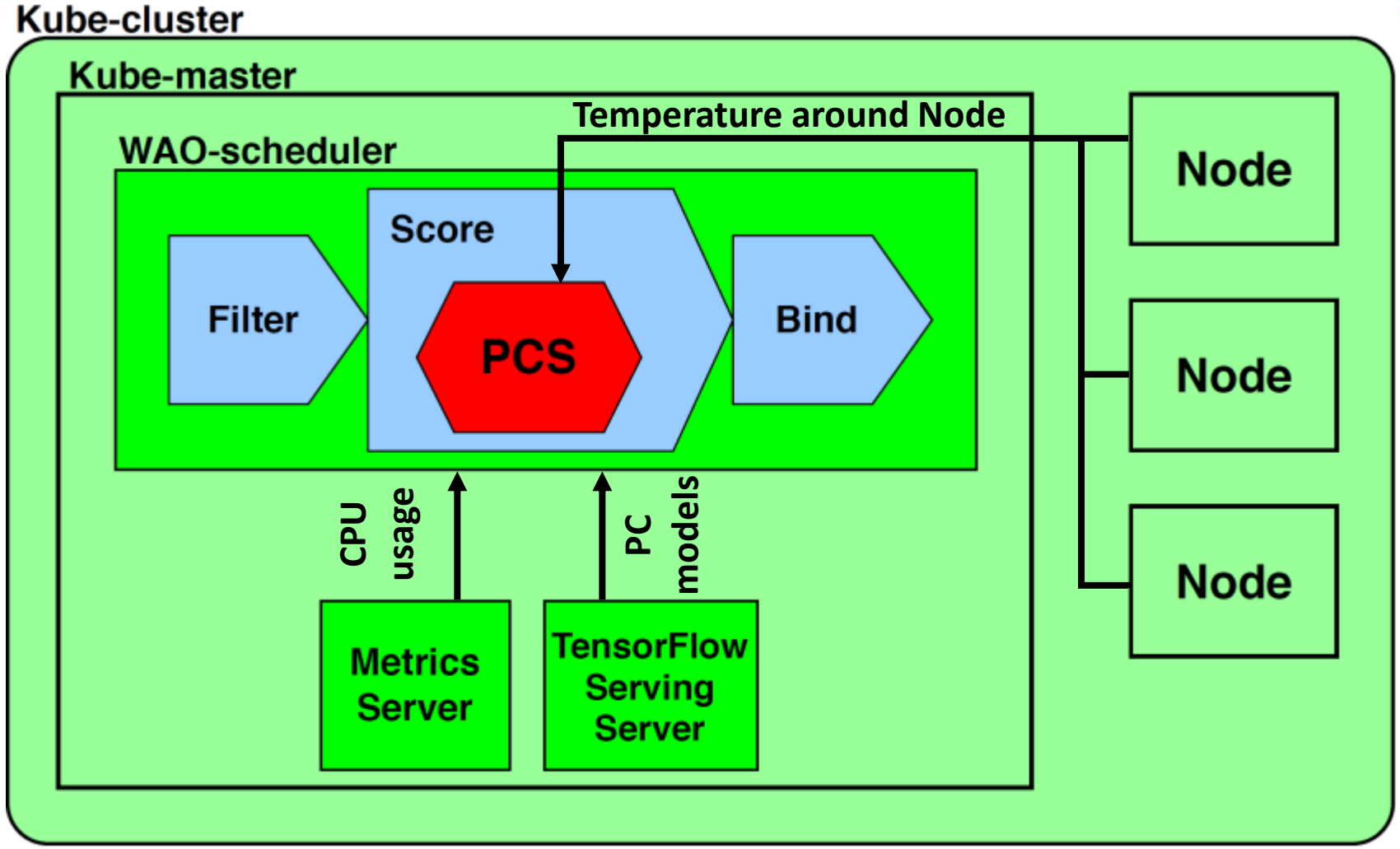
Metal LB	WAO-LB
Load Balancing	Response time priority control
	Power consumption priority control
	Power Consumption + Response Time

Scheduler Framework on K8s



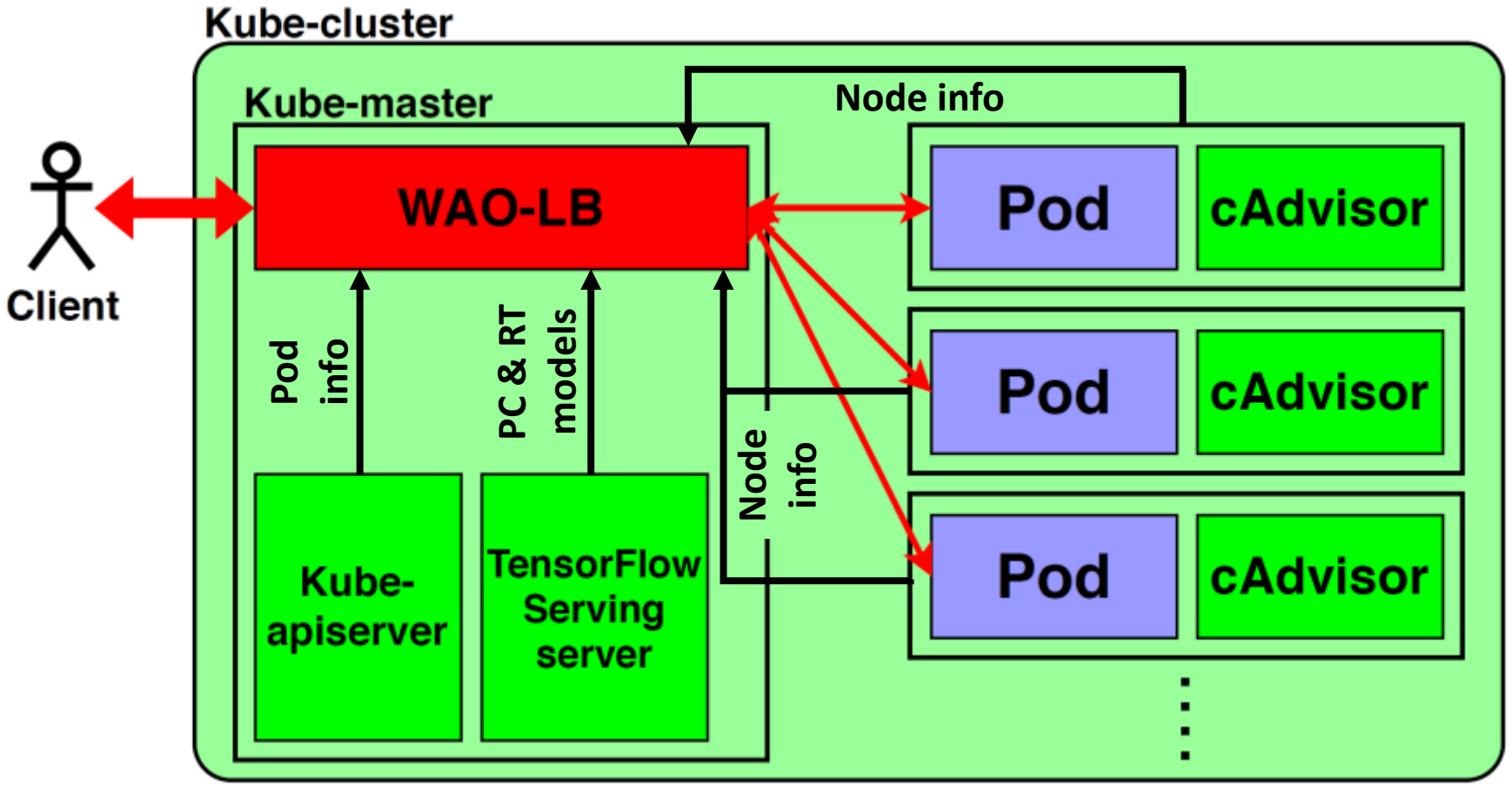
PCS : Power Consumption based Scorer

Architecture of WAO Based Scheduler



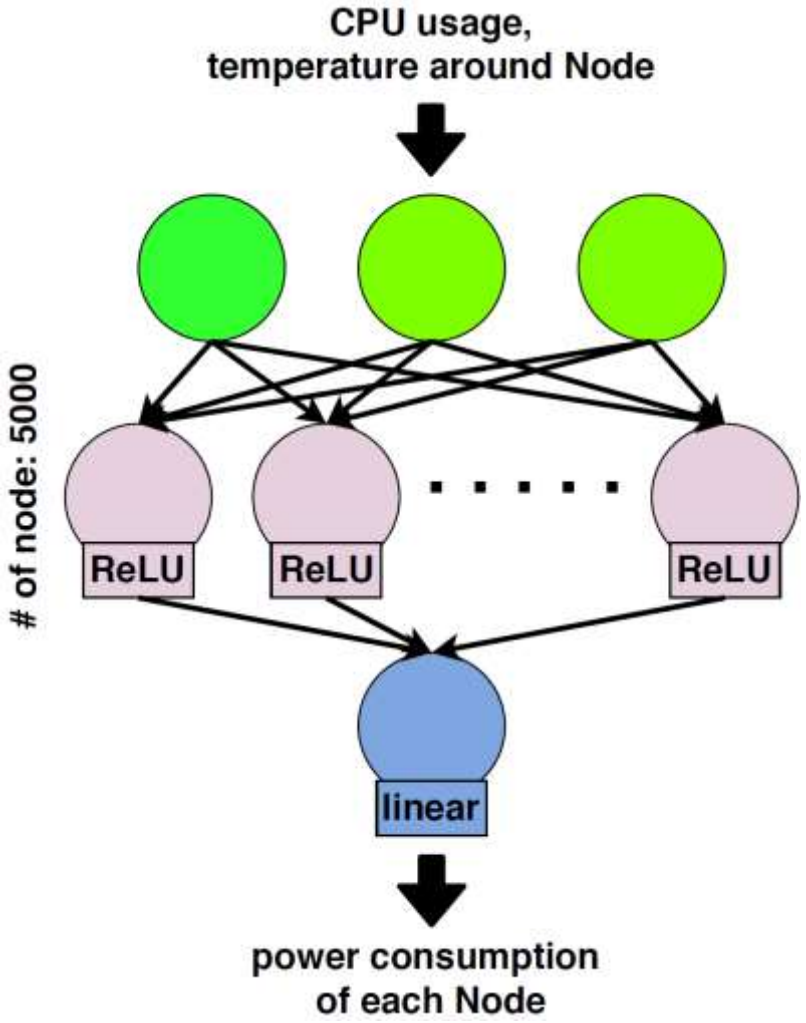
PCS : Power Consumption based Scorer

Architecture of WAO Based Load Balancer

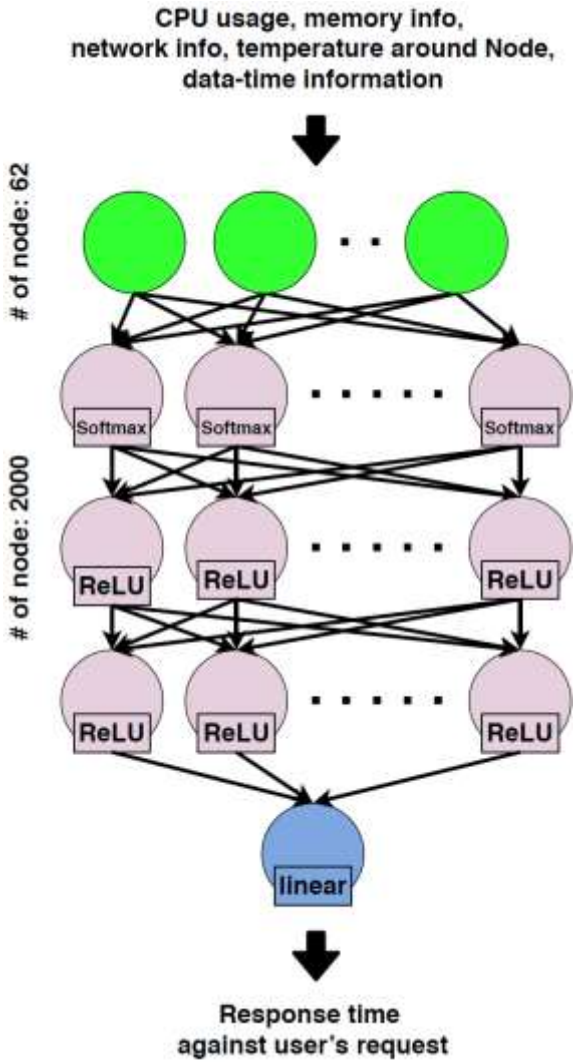


Setting of Machine Learning

Power consumption (PC) model



Response time (RT) model



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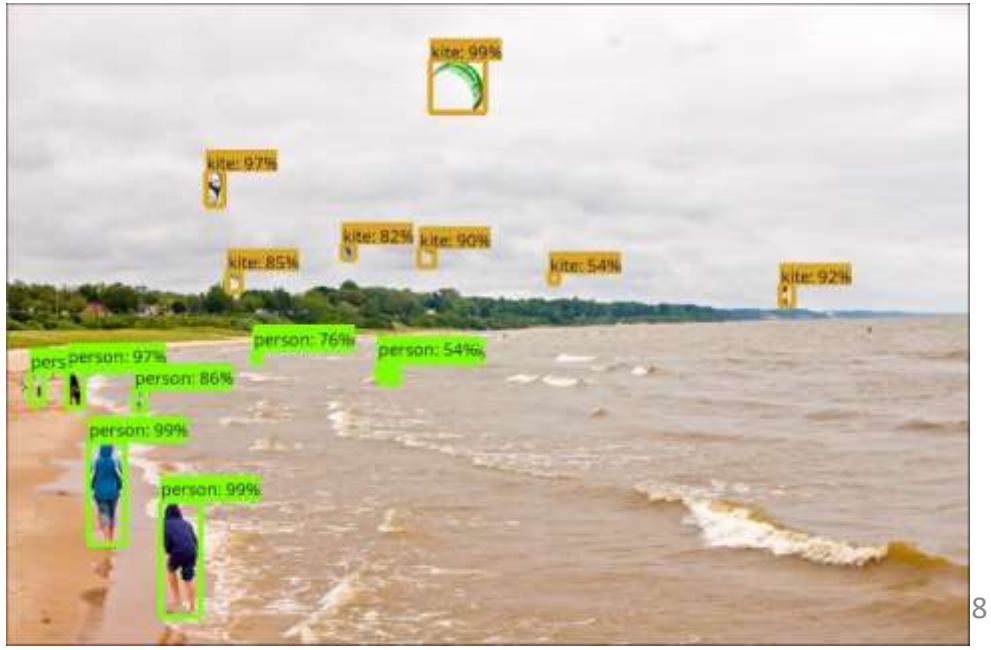
How does it work? How is the performance?

Environment

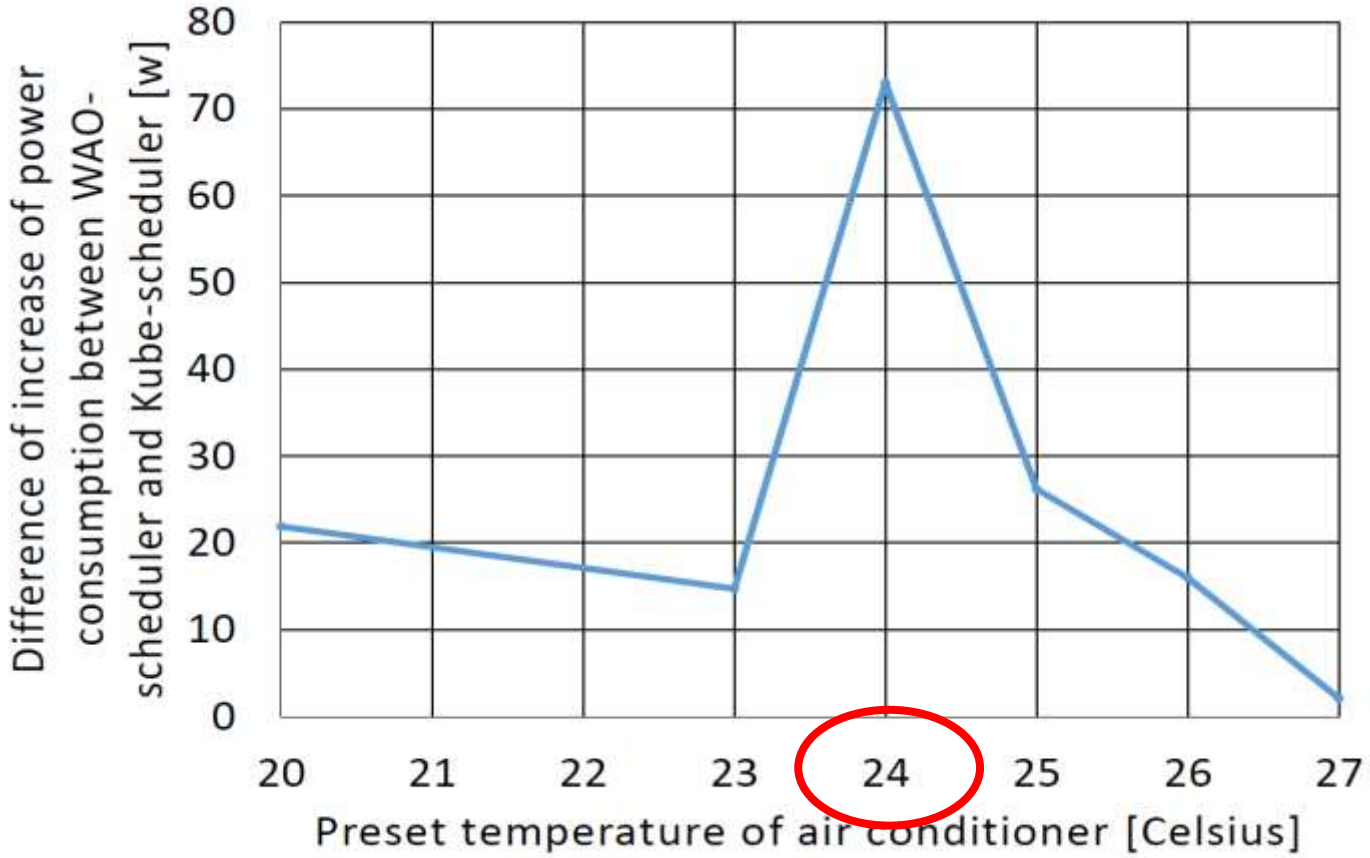
- A real private data center
  with about 200 servers located in Osaka, Japan
- Each servers with two Intel Xeon Silver 4108 CPUs (8 cores × 2),
  16 GB of memory, and a 1 TB HDD

Microservices Application

- Used a service that performs object detection



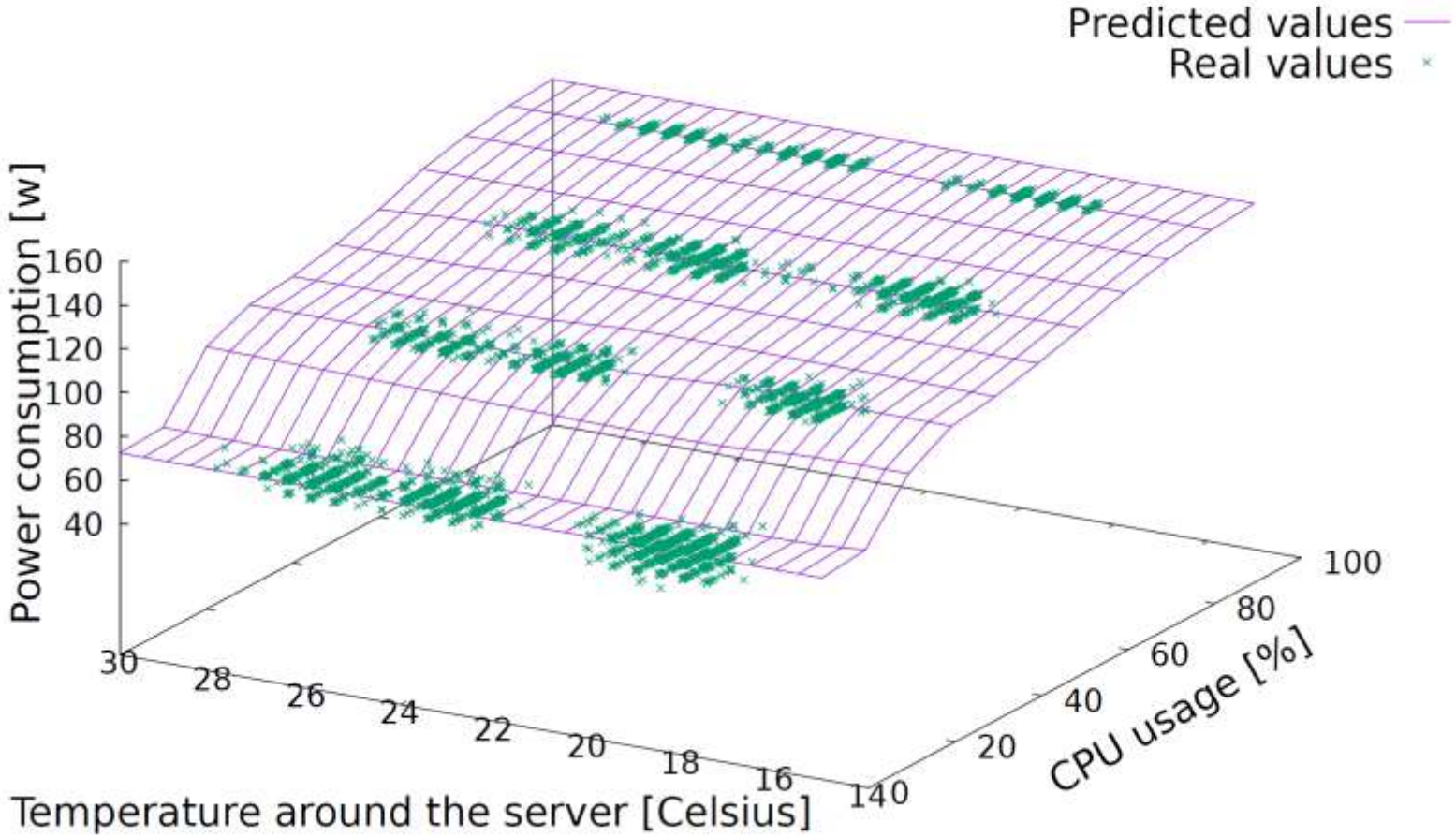
Preset Temperature of Air Conditioner



When the preset temperature was 24℃,
WAO-scheduler reduced most power consumption

- fix the temperature parameter at 24℃

Power Consumption Model



Significant increased in PC

between CPU usage of 10% and 30%

Evaluation Value in WAO Based Load Balancer

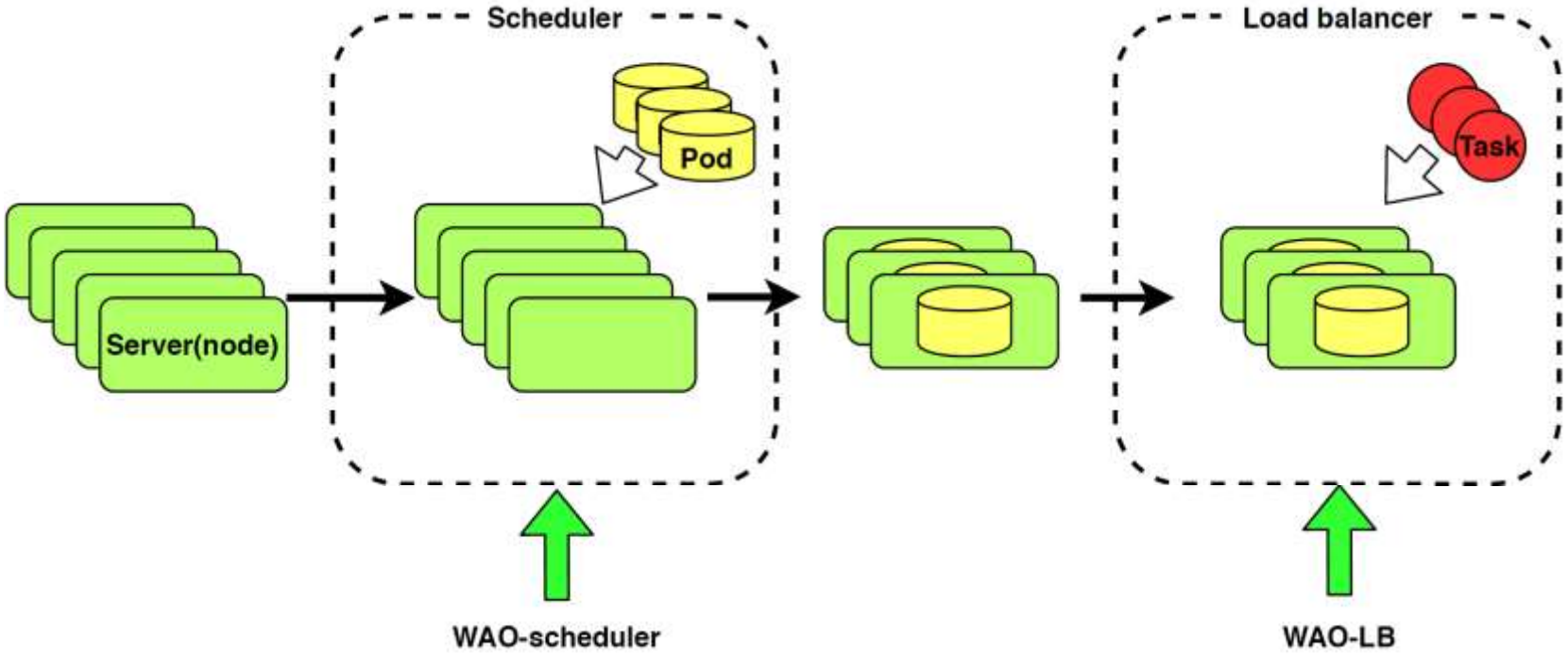
$$Evaluation\ Value = \alpha PC + \beta RT$$

- PC, RT: indexes: increase of Power Consumption and Response Time
- α, β: weights of each index ($\alpha + \beta = 1$)

- Get values of *PC* and *RT* using neural network
- Decide α and β according to operating requirements
  - Autonomous driving: response time is critical
  - Non-real-time related application:
    lowering power consumption can be prioritized

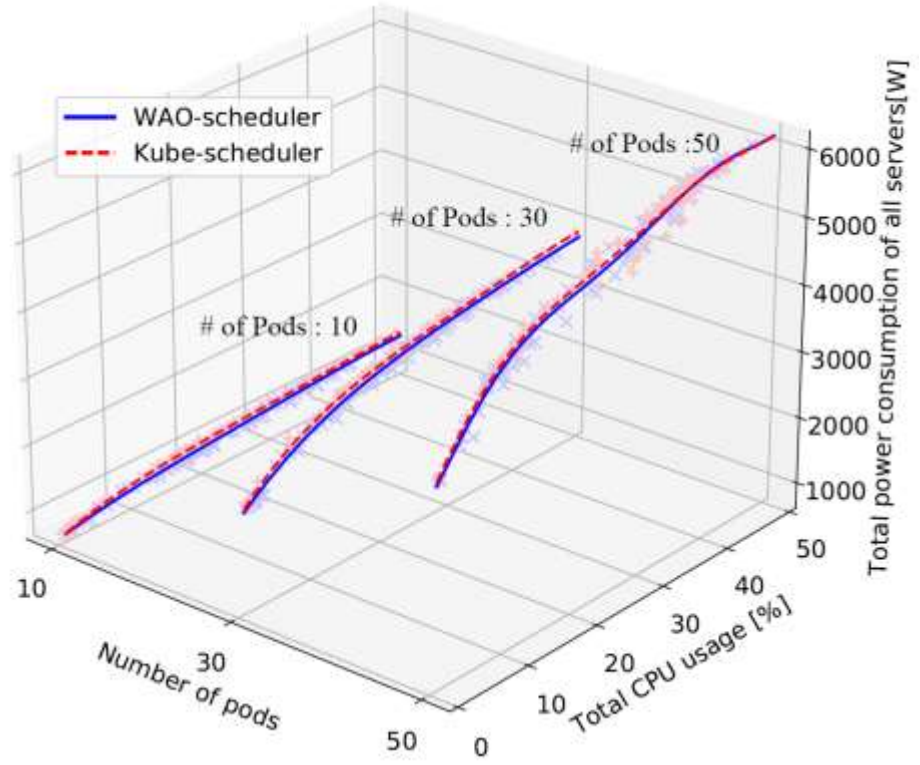
✓Correlation between *PC* and *RT*: -0.569

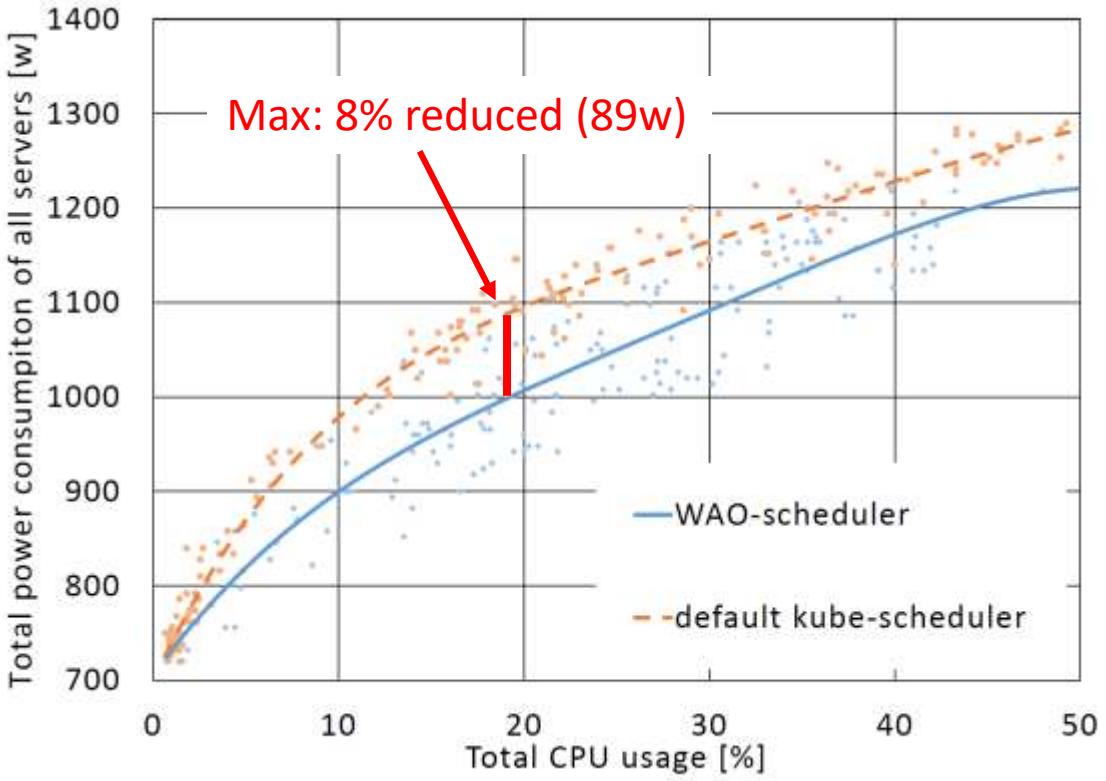
Evaluation of Power Consumption Reduction



	WAO-LB	MetalLB
WAO-scheduler	③	①
default Kube-scheduler	②	Baseline

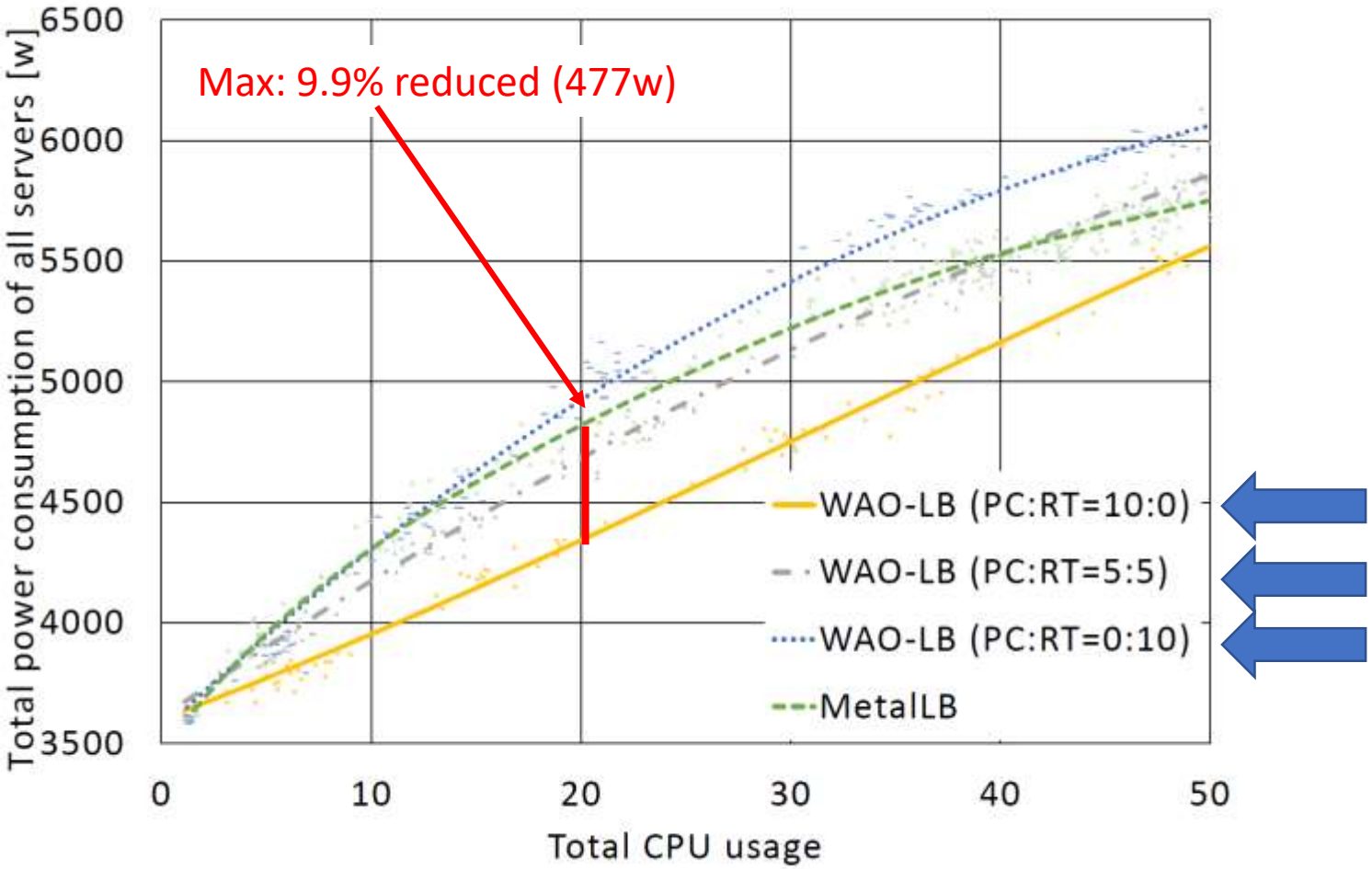
Evaluation of "WAO Scheduler" + MetalLB





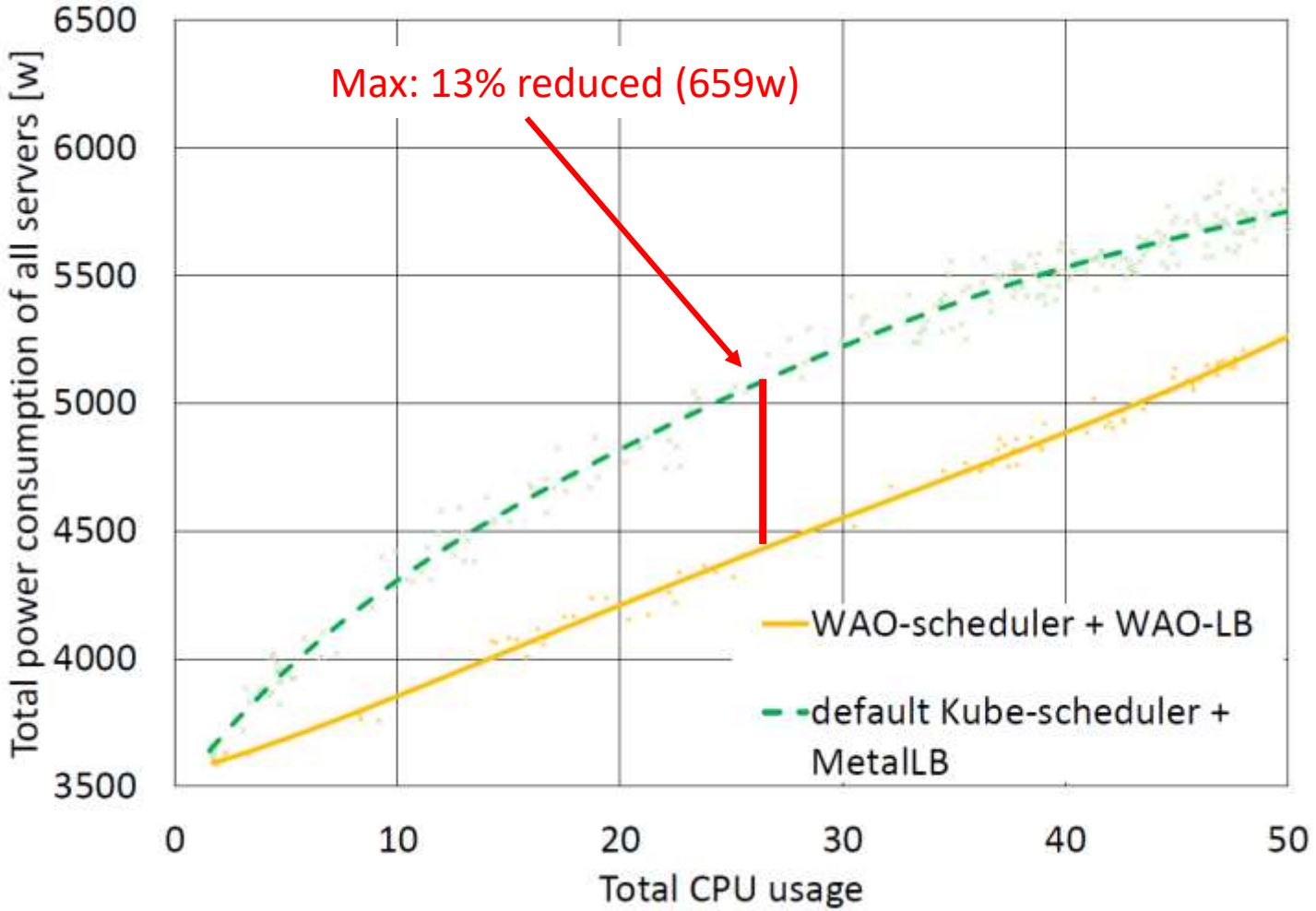
1. Achieved power saving in allocating 10, 30, and 50 Pods
2. Consumed about 8% less power compared to the Kube-scheduler
   - Total CPU usage : 20%
   - Number of Pods : 10

Evaluation of Kube Scheduler + “WAOLB”



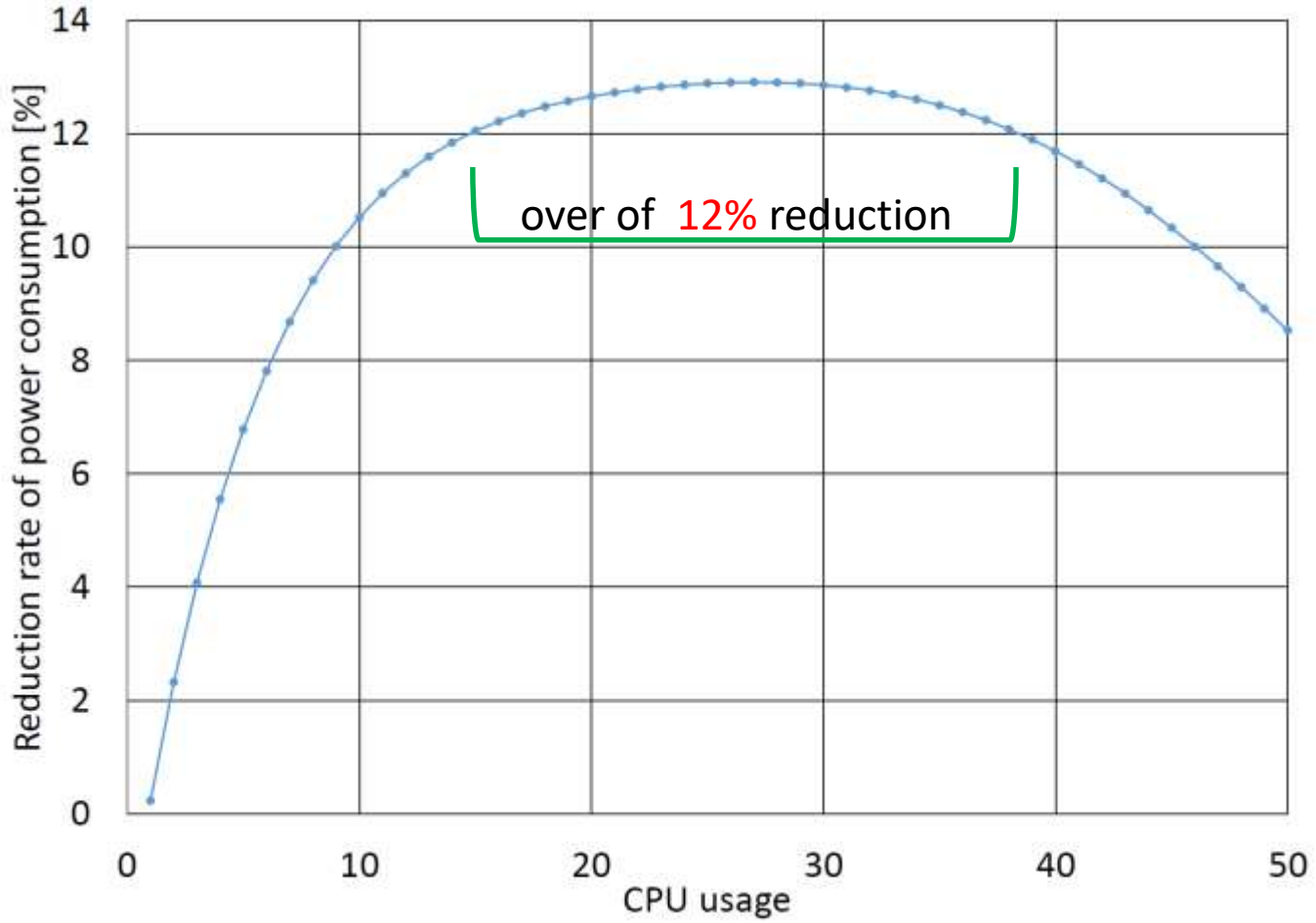
- About 9.9% less power consumption than MetalLB at the total CPU usage of 20% (WAO-LB (PC:RT=10:0))

Evaluation of complete K8s-WAO solution



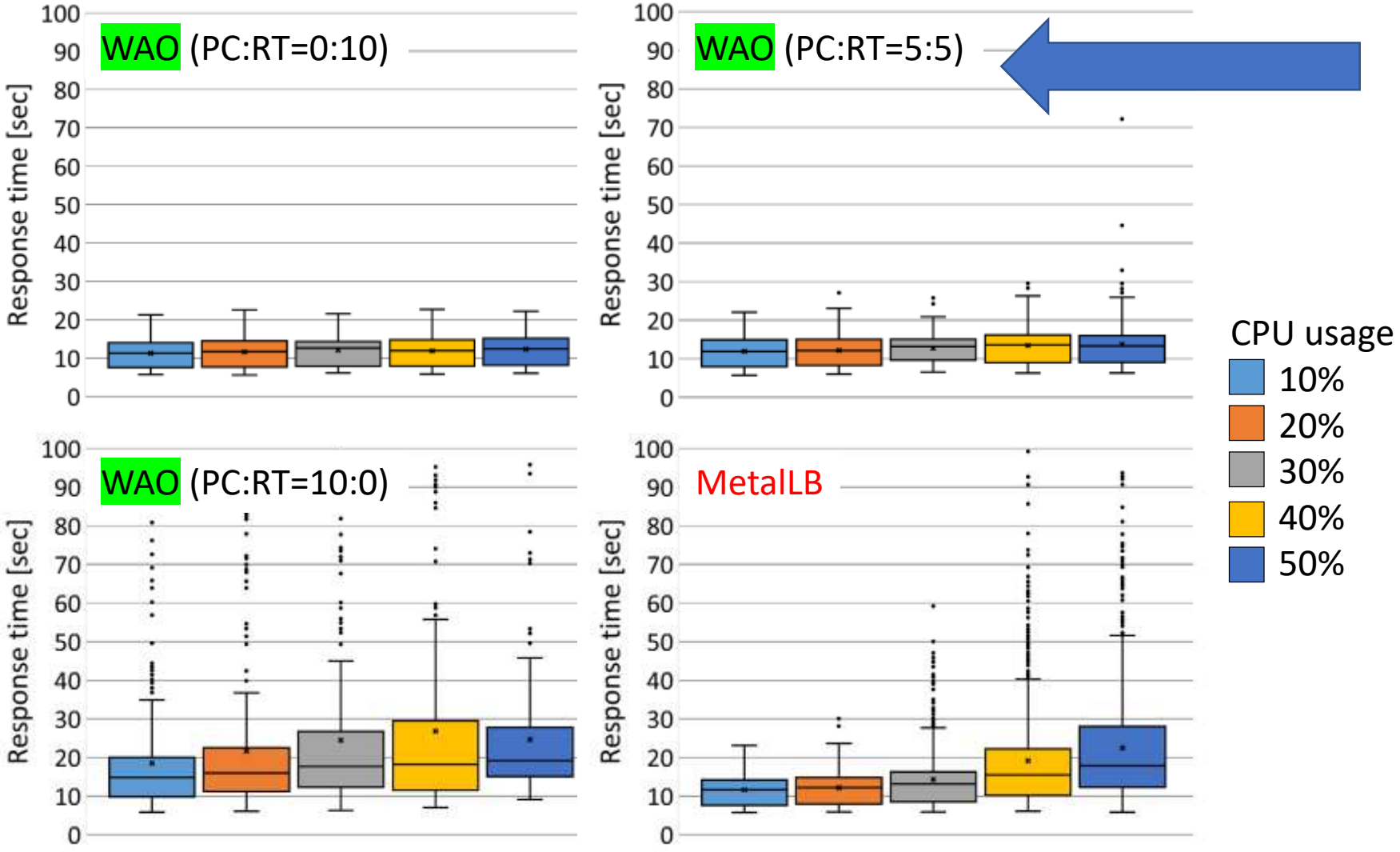
- About 13% less power consumption than default Kube-scheduler + MetalLB

Evaluation of Kubernetes-based WAO



- K8s-based WAO reached over of 12% reduction at the total CPU usage of 15-39%

Evaluation of Response Time



Conclusion

- A WAO (workload allocation optimizer) to K8s platform for optimizing power consumption

- Power consumption reduction

	WAO-LB	MetalLB
WAO-scheduler	13%	8%
default Kube-scheduler	9.9%	baseline

- According the response time requirements of applications, WAO-LB can achieved great power consumption reduction

Thank you

For your attention!

Any Questions

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