Compute Continuum
Managing Resources between Cloud, Edge, and Endpoint

A **Lecture** and **Demo** by **Matthijs Jansen**

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@Large Research
Massivizing Computer Systems

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Continuum
Open-source Code

Compute and Data Offloading

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Requirement: Process live video

Problem: Little resources for native processing
Solution: Offload data to other devices

Offloading Scenarios

There are many offloading scenarios

Many questions to answer:

- Where to offload from/to?
- Available resources?
- Application requirements?

Compute Continuum in 3 Layers

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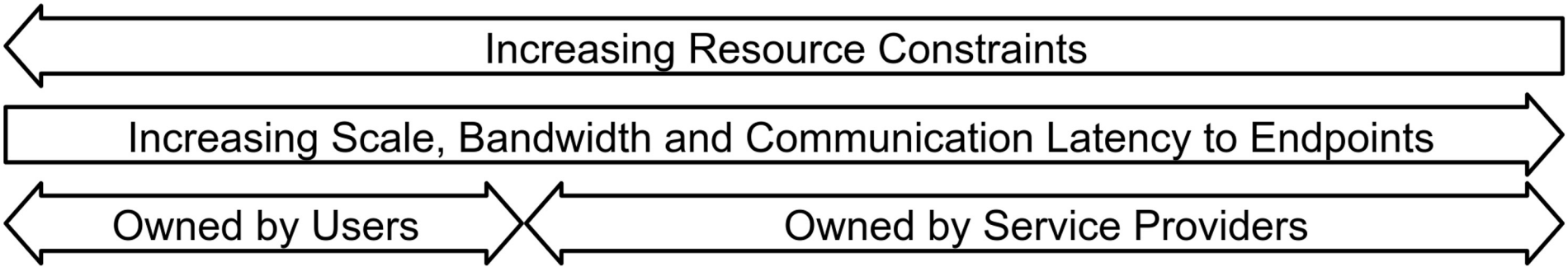

Endpoint

- Generates data through users and sensors
- Native processing requires no offloading
- No need to share resources
- Limited resources and energy
- Mobile

Compute Continuum in 3 Layers

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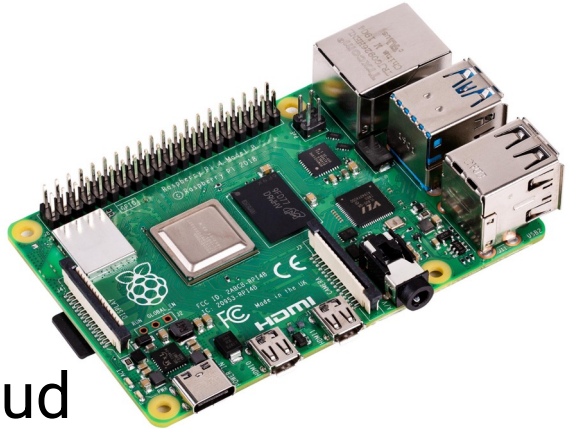
Increasing Resource Constraints

Increasing Scale, Bandwidth and Communication Latency to Endpoints

Owned by Users | Owned by Service Providers

- More resources than endpoints
- Low latency to endpoint and cloud



Edge

- Limited reliability
- Offload target for endpoint users AND cloud services

Compute Continuum in 3 Layers

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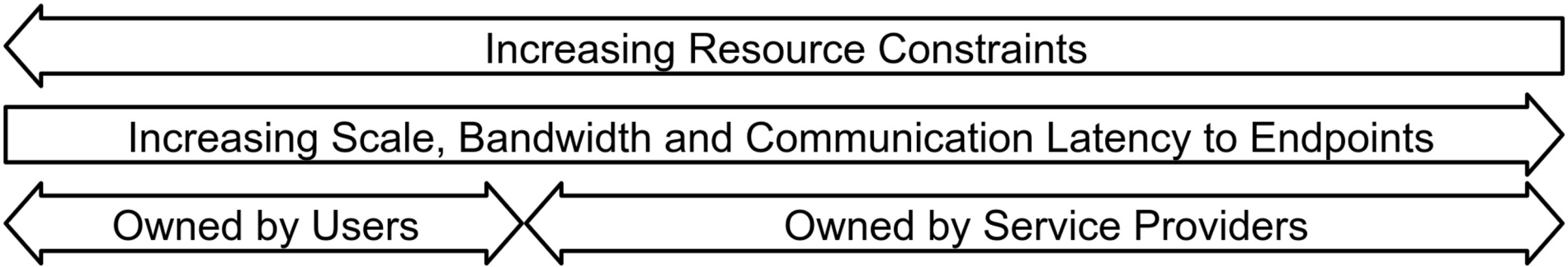

- High latency to endpoints
- Owned by cloud provider (privacy?)
- Near-infinite resources
- Variety of services

Cloud

Compute Continuum in 3 Layers

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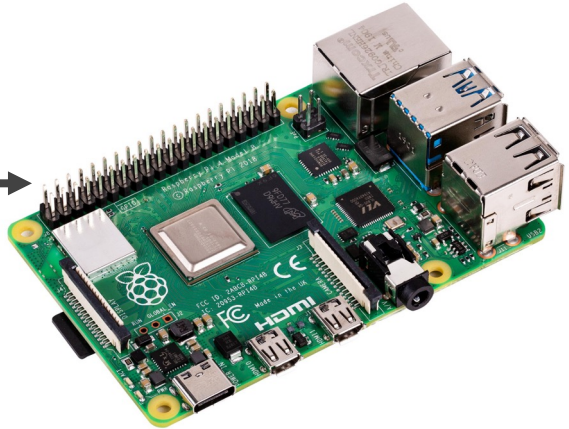
Increasing Resource Constraints

Increasing Scale, Bandwidth and Communication Latency to Endpoints

Owned by Users

Owned by Service Providers



Endpoint

Edge

Cloud

Offloading Choices: Big Impact

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Time to process 1 image

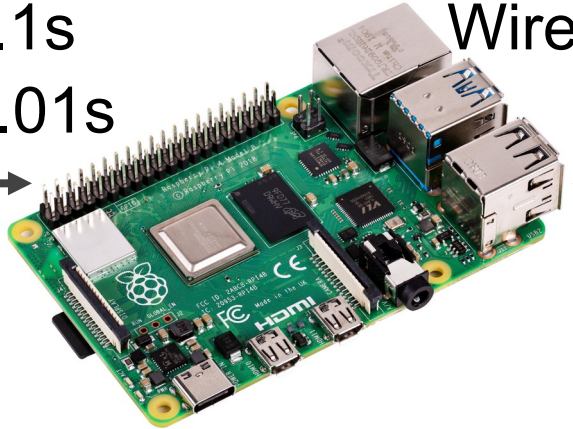
Native: 1s

Edge: .5s

Cloud: .2s

WiFi: .1s

Wired: .01s



Wired: .05s

Endpoint

Edge

Cloud

Offloading Choices: Big Impact

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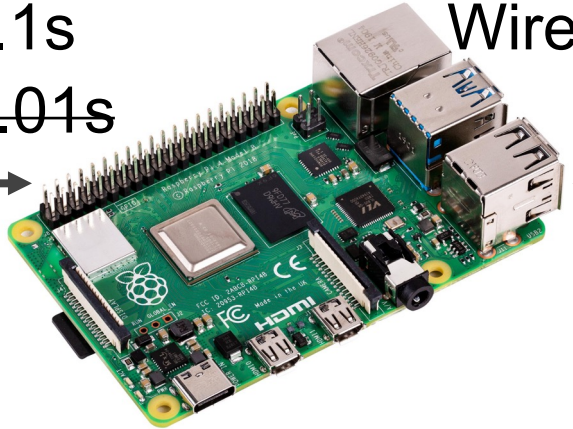
Time to process 2 images in parallel

Native: 1s Edge: .8s Cloud: .3s

WiFi: .1s

~~Wired: .01s~~



Wired: .01s

Endpoint Edge Cloud

Offloading Choices: Big Impact

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How do I find a deployment in the Compute Continuum that works best for my requirements?

How Do I Use the Compute Continuum?

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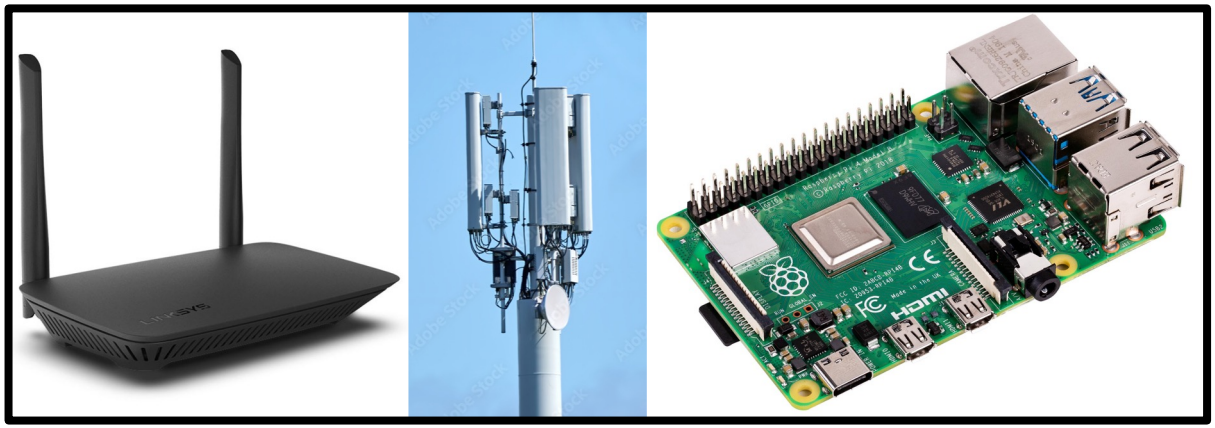
Software dev.
How to test software across devices?

Service provider
How to offer services across all devices?



Challenges in the Compute Continuum

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Q1: Where to deploy?

Need access to infrastructure

→X86 vs ARM

→Wired vs Wireless

→**Expensive!**

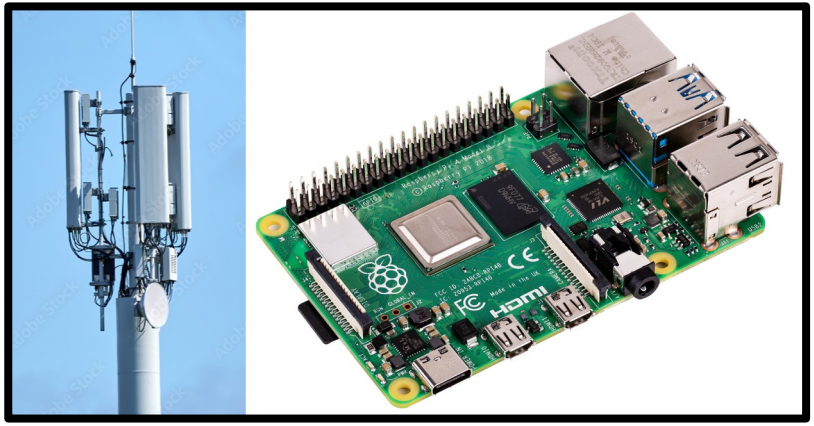
Q2: What software to deploy?

Layers have different requirements

→Tensorflow vs Tensorflow Lite

→Kubernetes vs KubeEdge

→**Takes a lot of time!**



Challenges in the Compute Continuum

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→**Takes a lot of time!**

<u>Conclusion:</u>

Problems are difficult to solve

→**What do we do?**

Continuum

Automated infrastructure and software exploration for the compute continuum

https://github.com/atlarge-research/continuum

Reference Architecture

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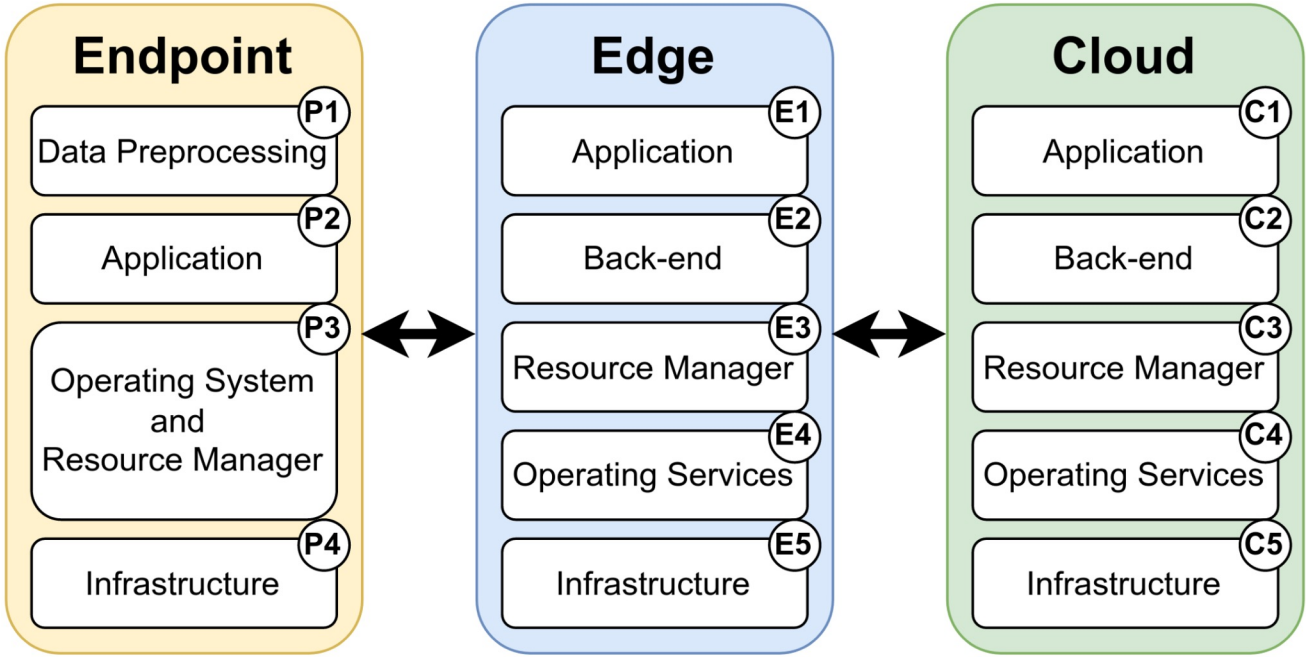
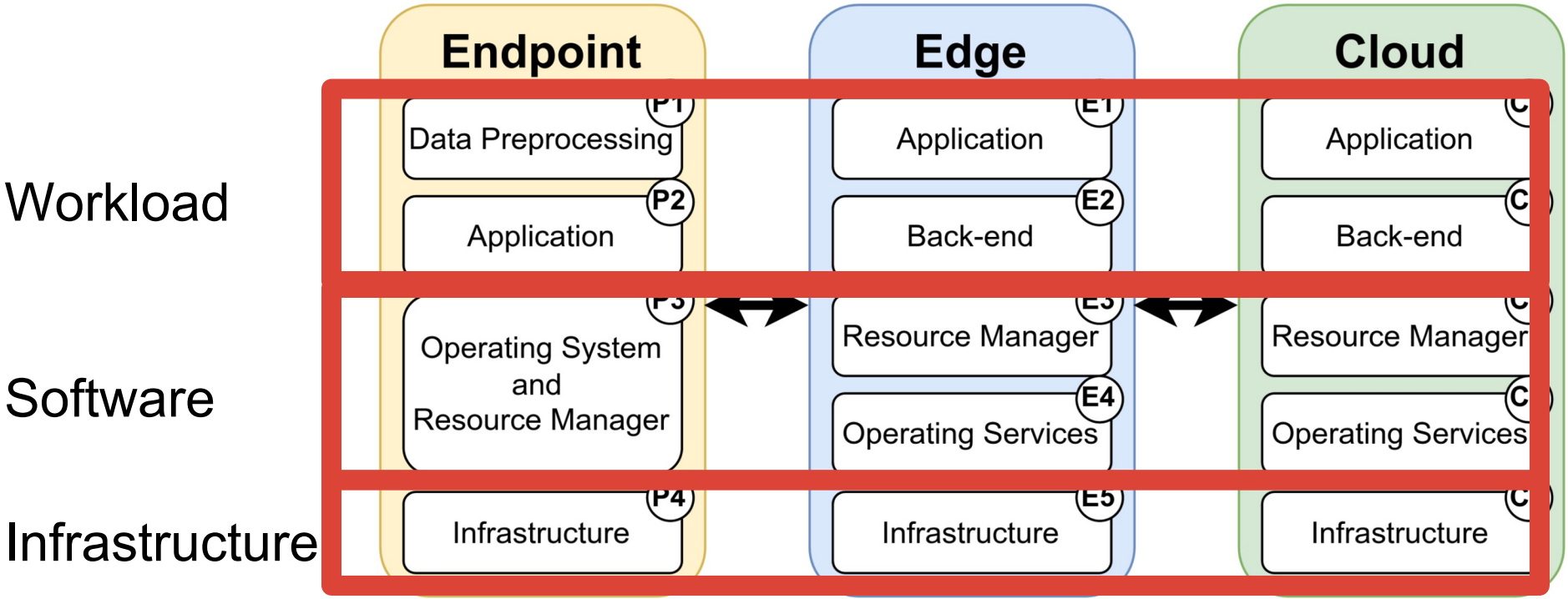
Compute Continuum Abstraction layers

Changing any layer impacts offloading

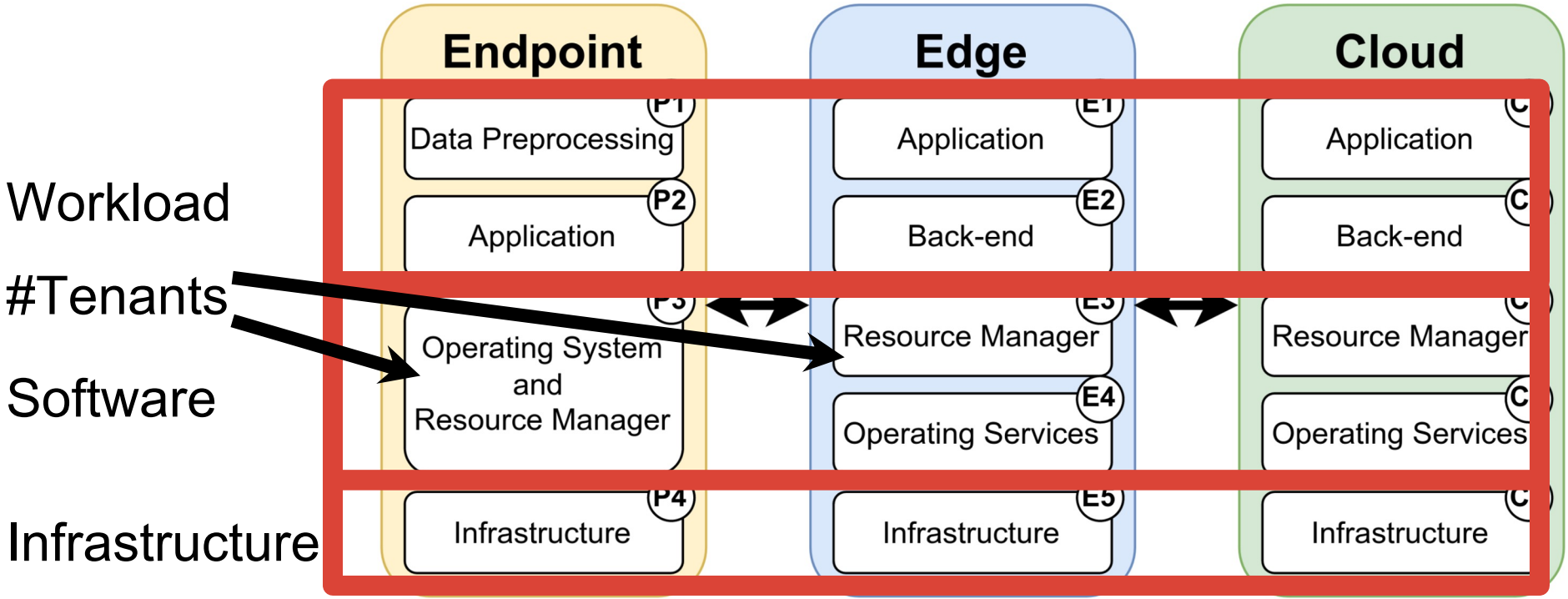


The SPEC-RG Reference Architecture for the Compute Continuum, Jansen et al, CCGRID'23

Reference Architecture Pillars



Reference Architecture Pillars



Reference Architecture Pillars

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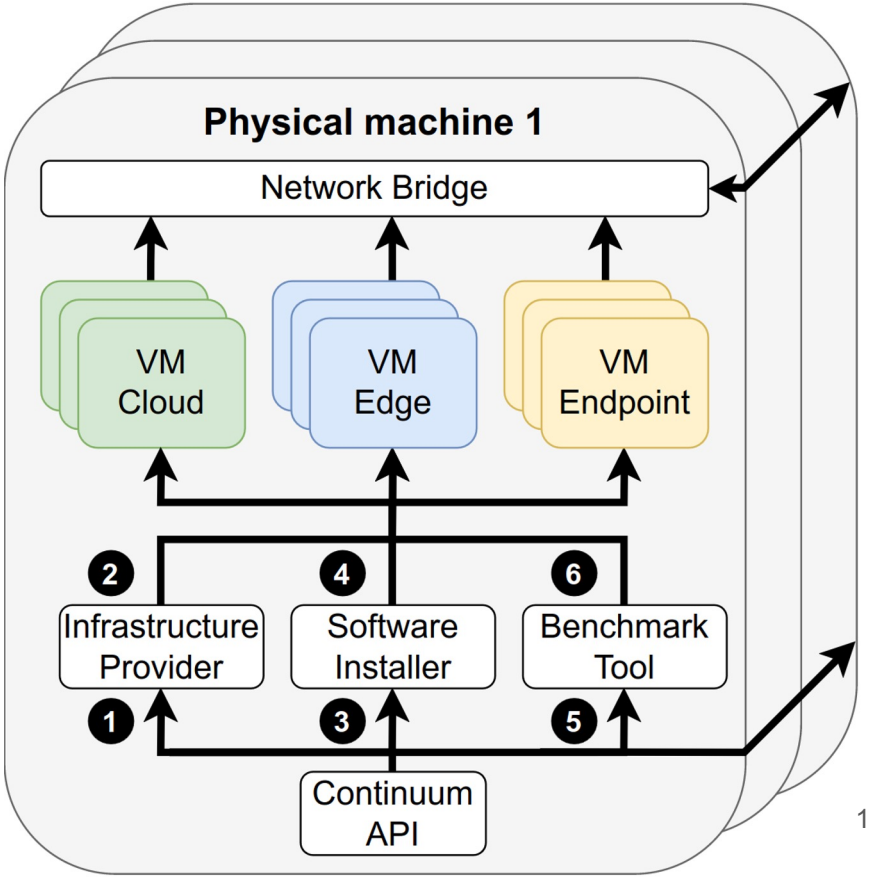
Goal

Build a deployment framework
where users can change any layer

The Continuum Framework

Execution phases:

1. Provision **infrastructure**
2. Install **software**
3. Benchmark **applications**



The Continuum Framework

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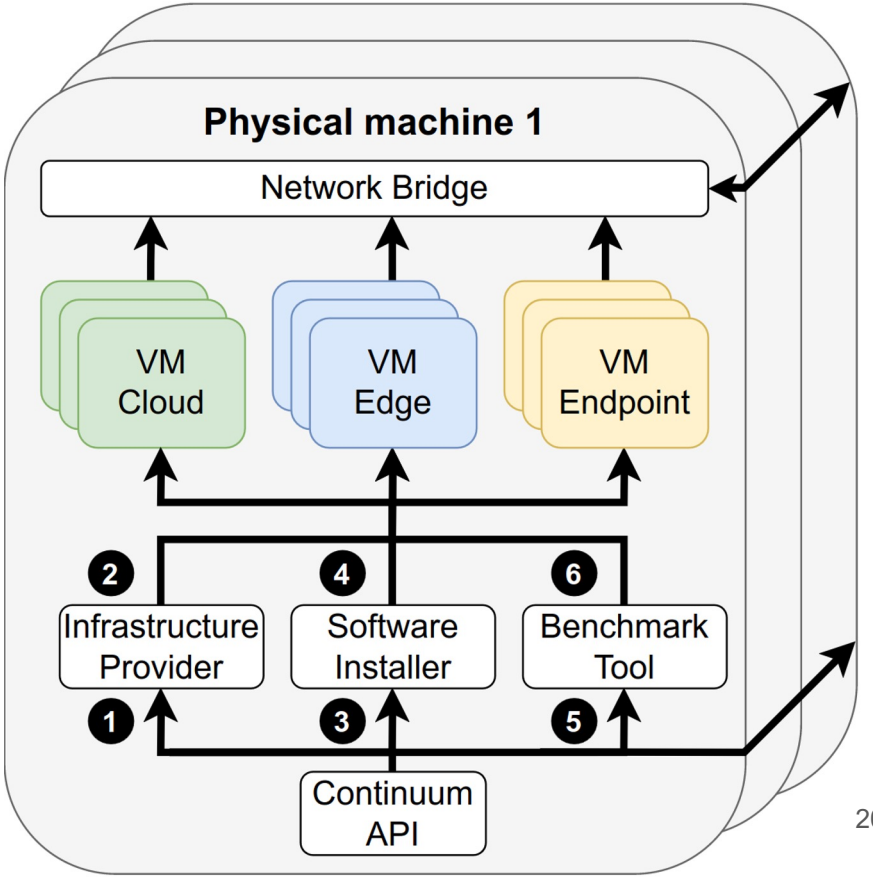
Design principles

1. Accurate
   → Deploy on hardware
1. Flexible
   → Emulate hardware and networks you have
1. Automated
   → Script deployments
1. Extendable
   → Components as modules



Today's Use Case

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Video camera processing
with image classification

- Generate X frames per second
- Analyze each frame with ML

ML can't run on endpoint
So, offload to cloud

Using cloud-native technologies

Step 1: Infrastructure Provisioning

config-file.cfg

[infrastructure]

provider = Local / QEMU

cloud vms = 2

cloud cores = 4

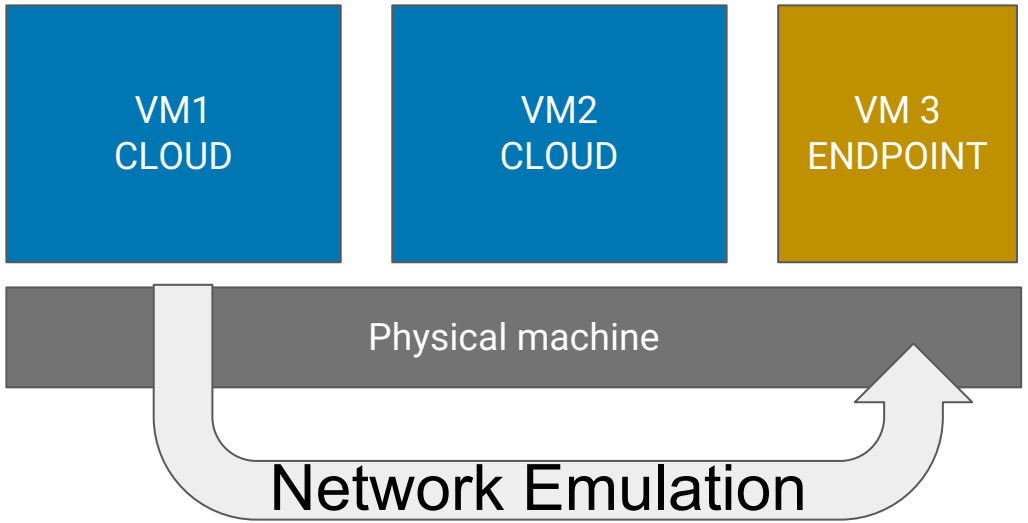
cloud memory = 16

endpoint vms = 1

endpoint cores = 1

endpoint memory = 0.5

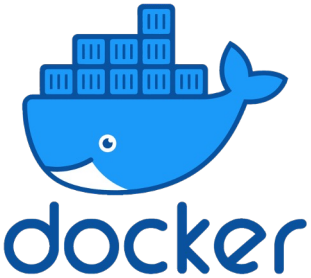
network = 4G



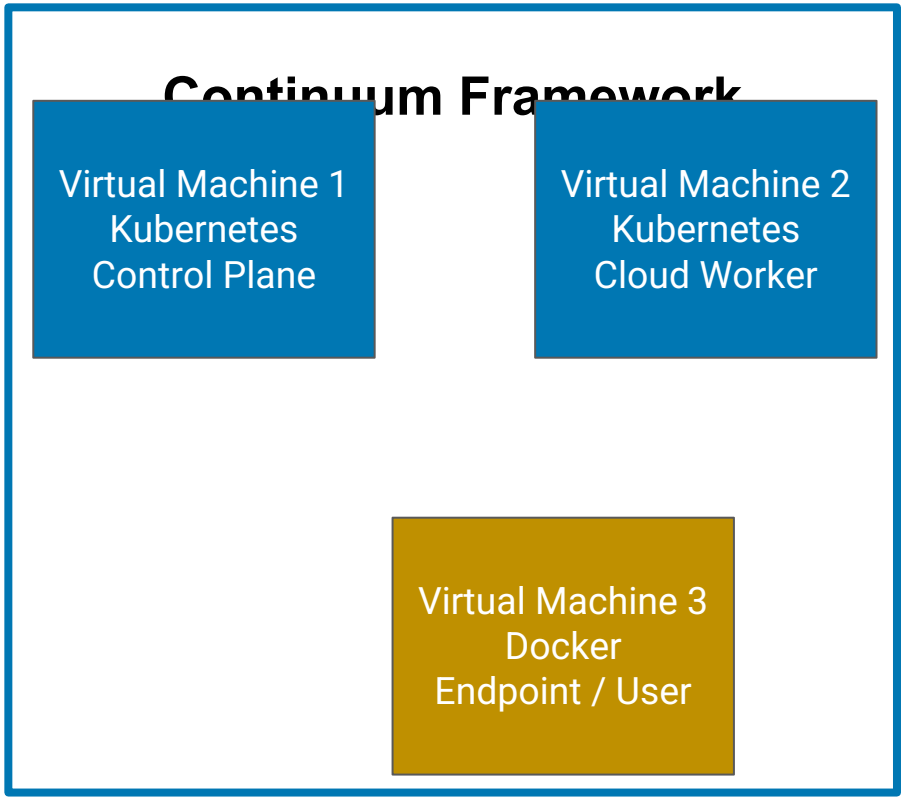
Step 2: Software Installation

config-file.cfg

resource manager = kubernetes



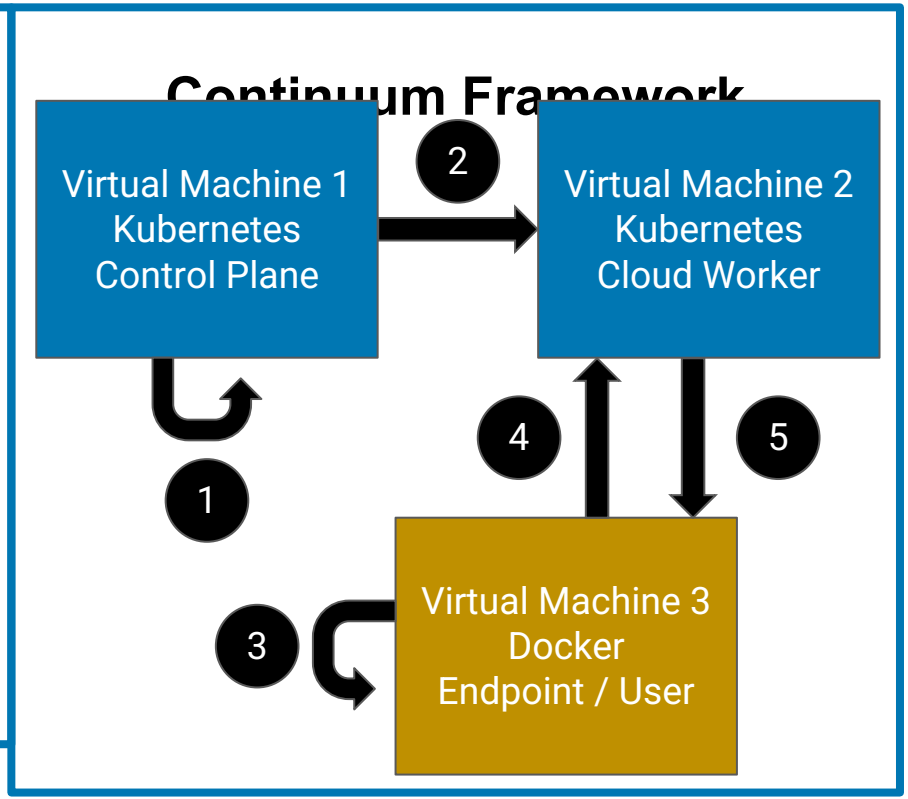
kubernetes



Step 2+3: Software and Benchmark

Software: Kubernetes + Docker

1. User registers app to K8s
2. Kubernetes deploys server component on cloud worker
3. User deploys generator component on endpoint
4. Generator sends data to cloud
5. Cloud processes data, sends result back to endpoint



Step 3: Benchmark Execution

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config-file.cfg

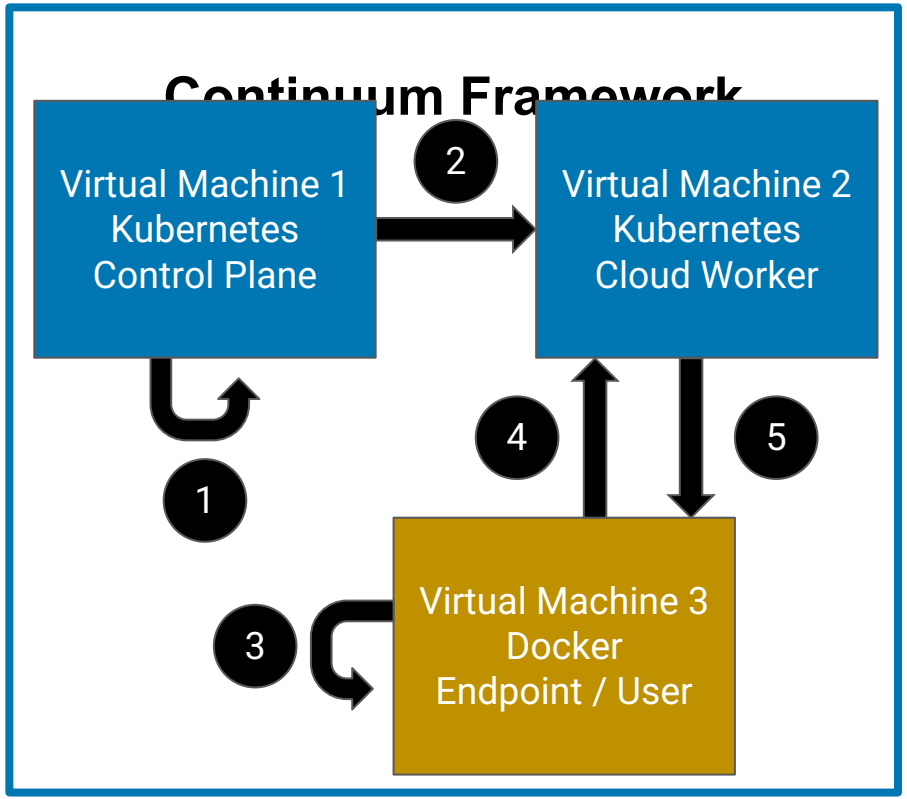
application = image class.

app cloud cpu = 1.0

app cloud memory = 3.0

app endpoint cpu = 1.0

app endpoint memory = 1.0



Step 4: Data Gathering & Visualisation

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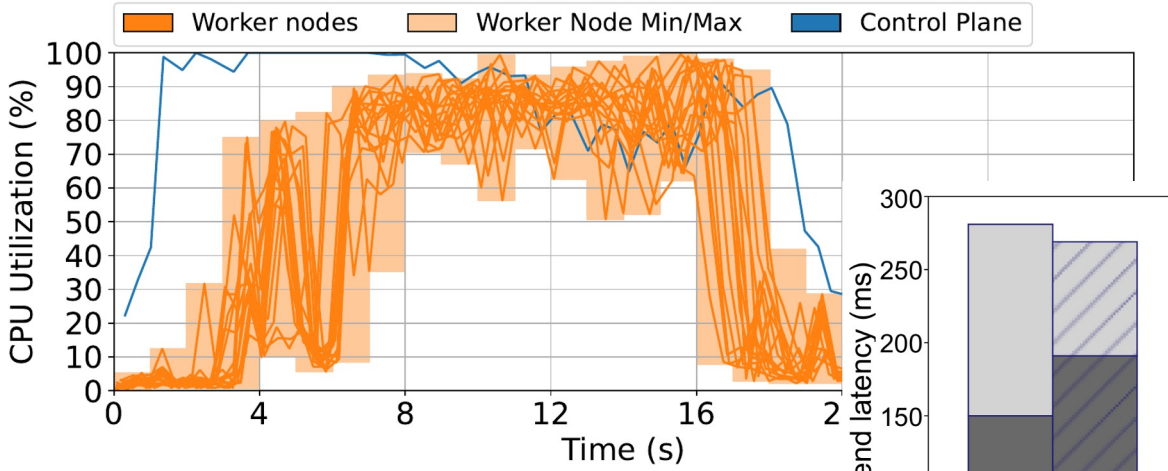

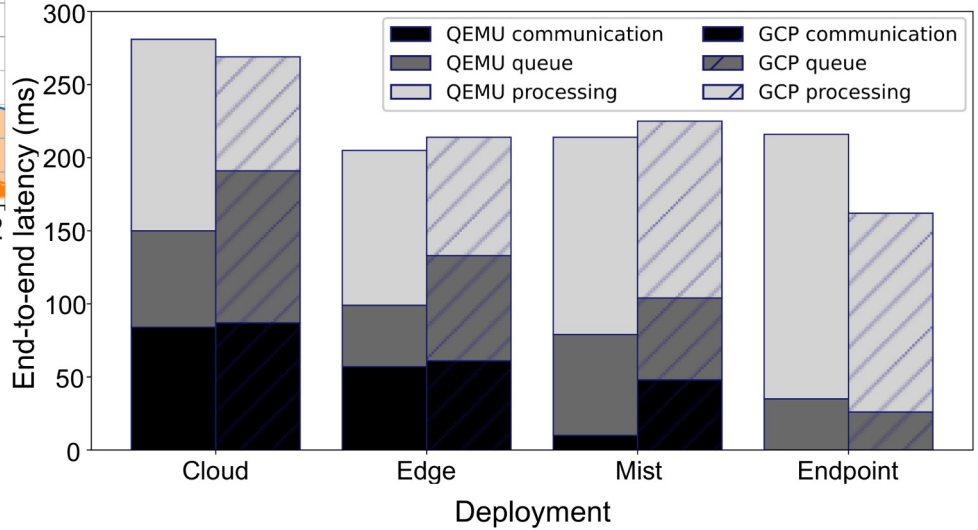

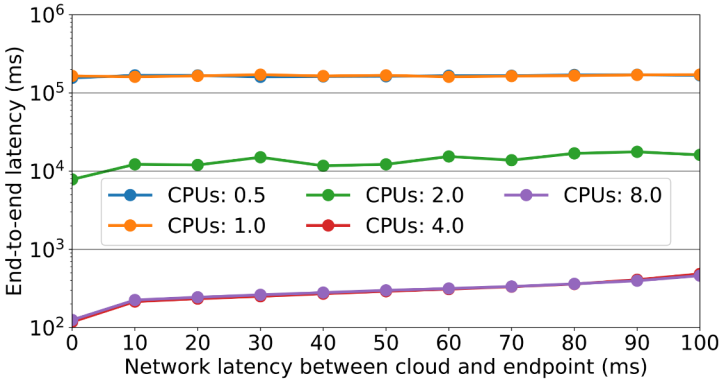

Today, You Will

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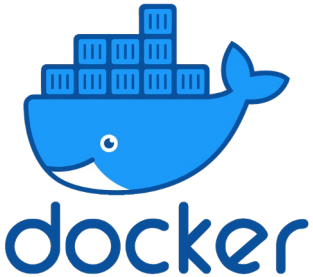
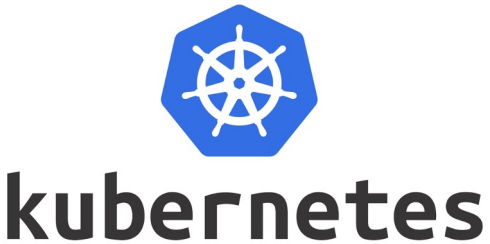
1. Deploy image classification app with Continuum, on VMs and Kubernetes
2. Get familiar with Kubernetes
3. Visualize cloud operations with Prometheus and Grafana
4. Deploy and instrument apps by hand on Kubernetes





Before We Start The Tutorial

- We provide access to hardware
- Send your PUBLIC SSH key to m.s.jansen@vu.nl (as text in the email and not as attachment)
- May need to group up depending on no. participants. If so, only 1 person per group sends SSH key

START HERE:

https://github.com/atlarge-research/continuum/tree/tutorial-2024