WIP: Exploiting Stochastic Performance Models to Estimate Energy Consumption of Software

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Introduction

- The ubiquity of ICT devices triggered a continuous digitalization of information

- Belkhir et al. estimate that ICT devices will produce 14% of global CO2 emissions by 2040 [1]

Crowds in St. Peter's Square [4]

2005

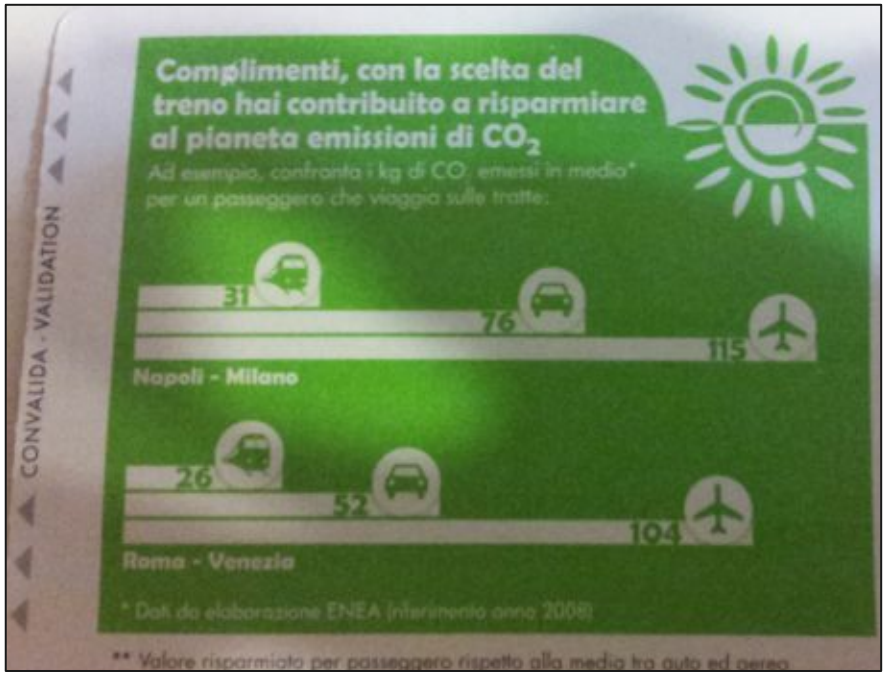
2013

Energy Transparency

Great achievements in HW power savings.

ARM Cortex-A35, 2015:

- 10% less power, 40% more performance than ARM Cortex-A7, 2011
- less than 4 mW of electrical power at 100 MHz [4]

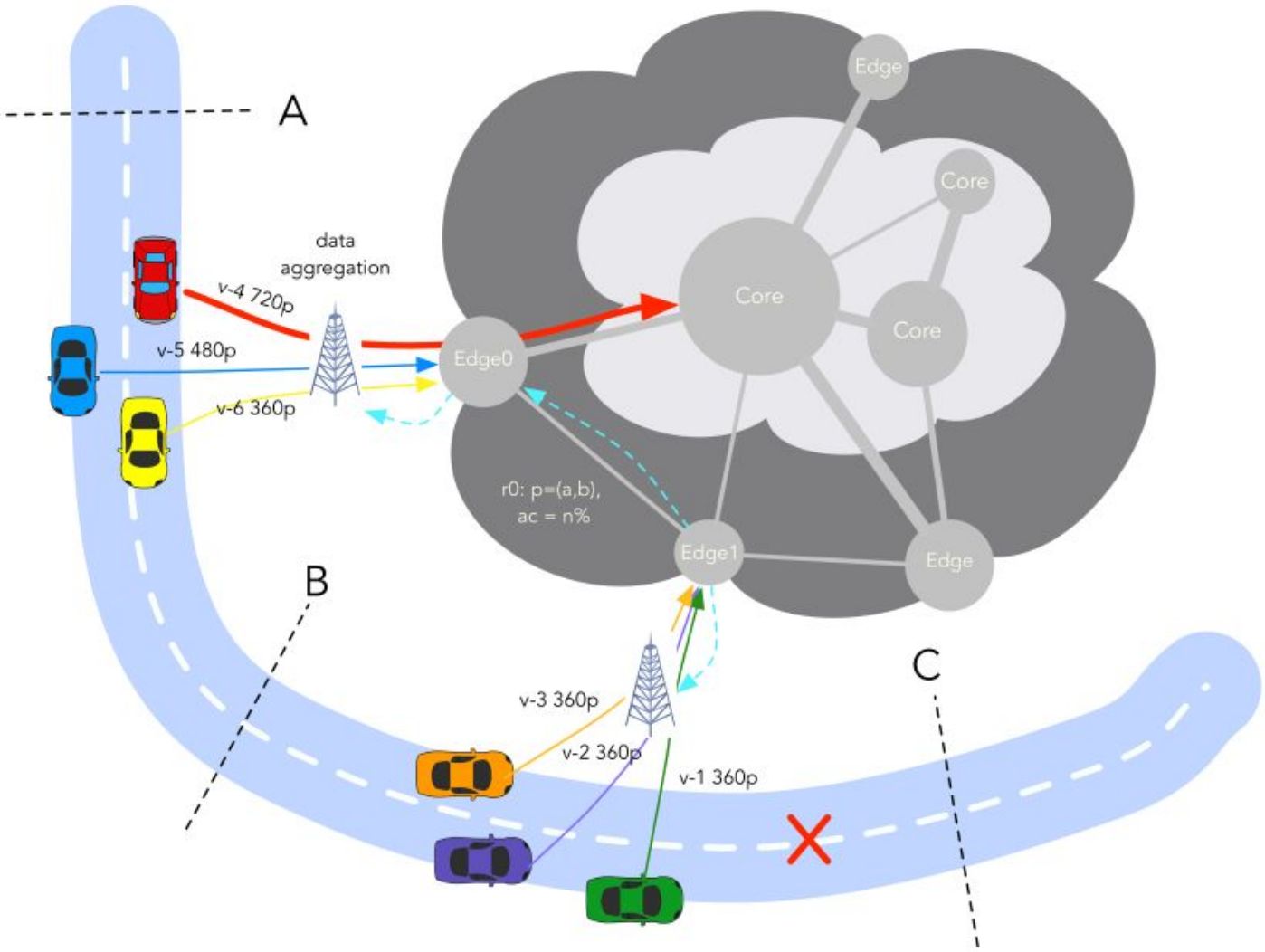


Trenitalia ticket showing emissions when traveling with different types of vehicles [4]

According to estimates, software accounts for **80%** of the energy used by embedded devices [2, 3]

Making developers aware of the impact of their decisions on software energy consumption

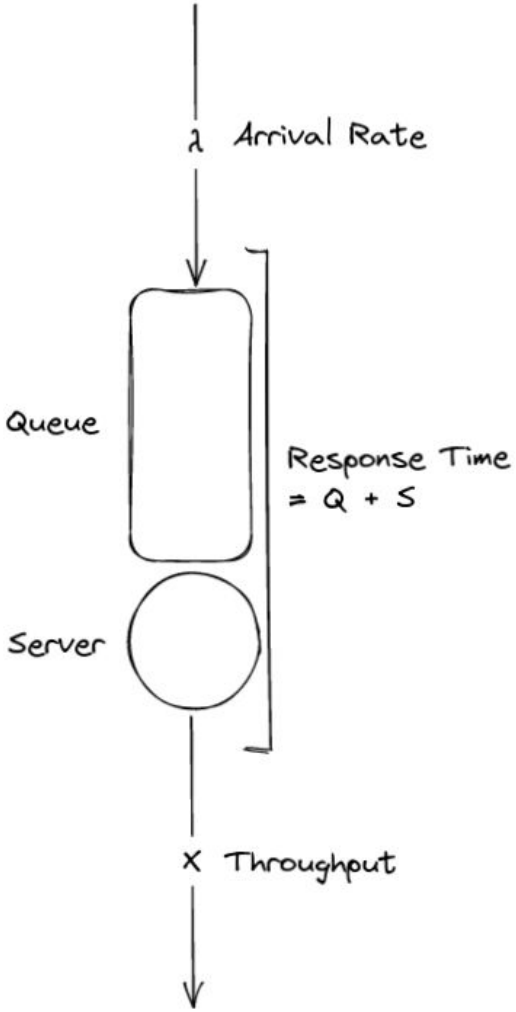
Facing the complexity of software



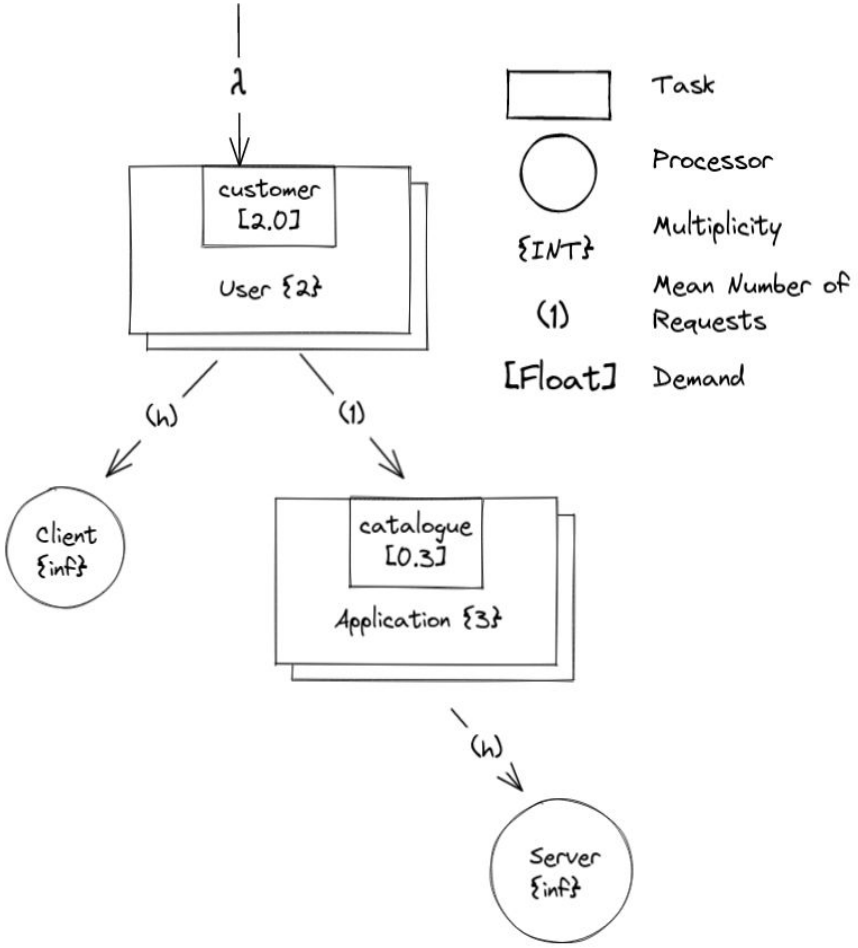
Edge cloud architecture of a distributed object detection application [5]

Modeling For Performance Estimation

A performance model represents how a behavior consumes the resources of a system



Queuing System



Layered Queuing Network (LQN)

Modeling For Performance Estimation

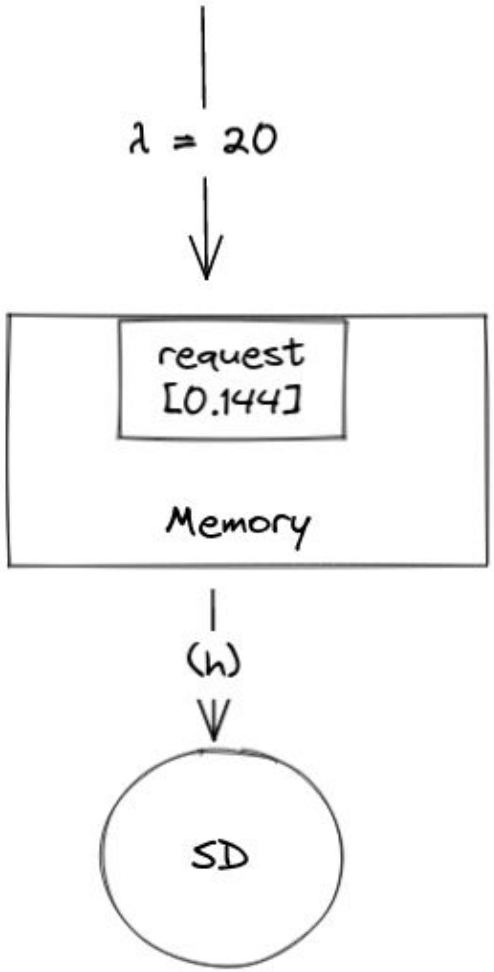
Let's estimate the performance of a memory

$$\lambda = \frac{A}{T} = \frac{20}{3} = 6.66 \frac{req}{s}$$

$$U = \frac{B}{T} = 0.96(96\%)$$

$$B = 0.96 \times 3s = 2.88s$$

$$S = \frac{B}{C} = \frac{2.88}{20} \frac{req}{s} = 0.144 \frac{req}{s}$$



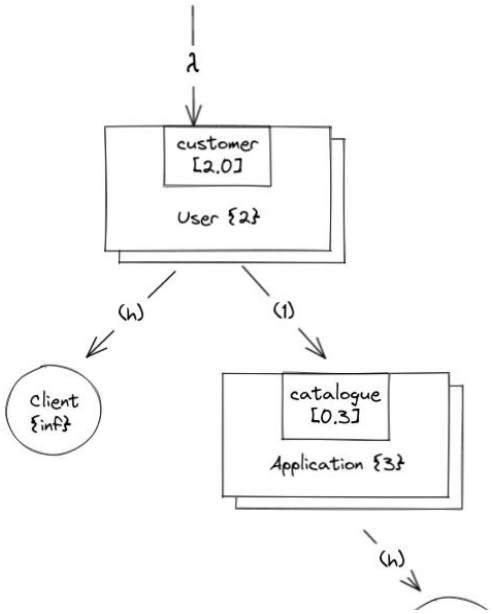
LQN of a Memory

The Research Idea

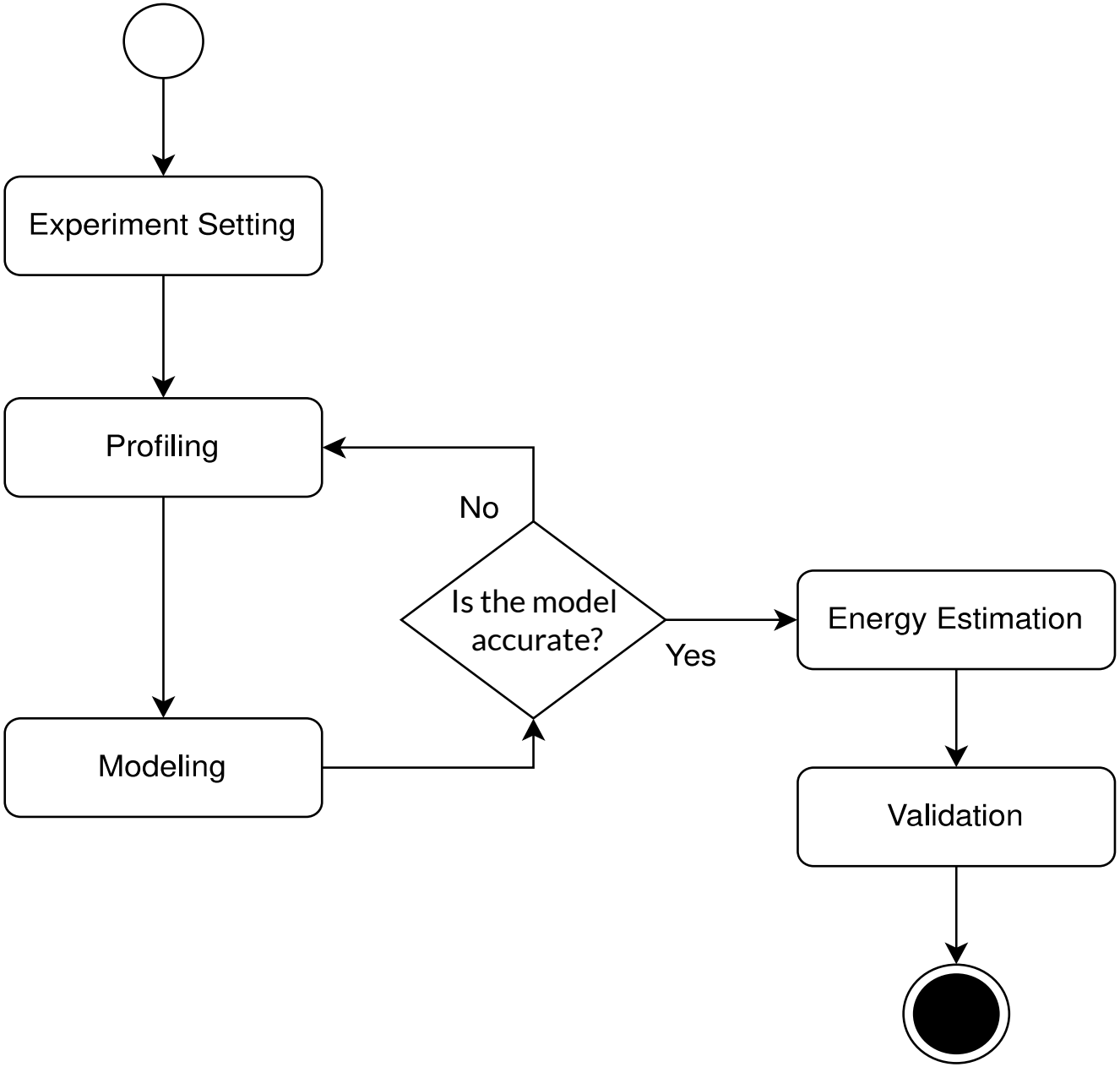
A company owns an e-commerce that receives transaction requests of different sizes.

Estimate the energy consumed when receiving larger size transactions

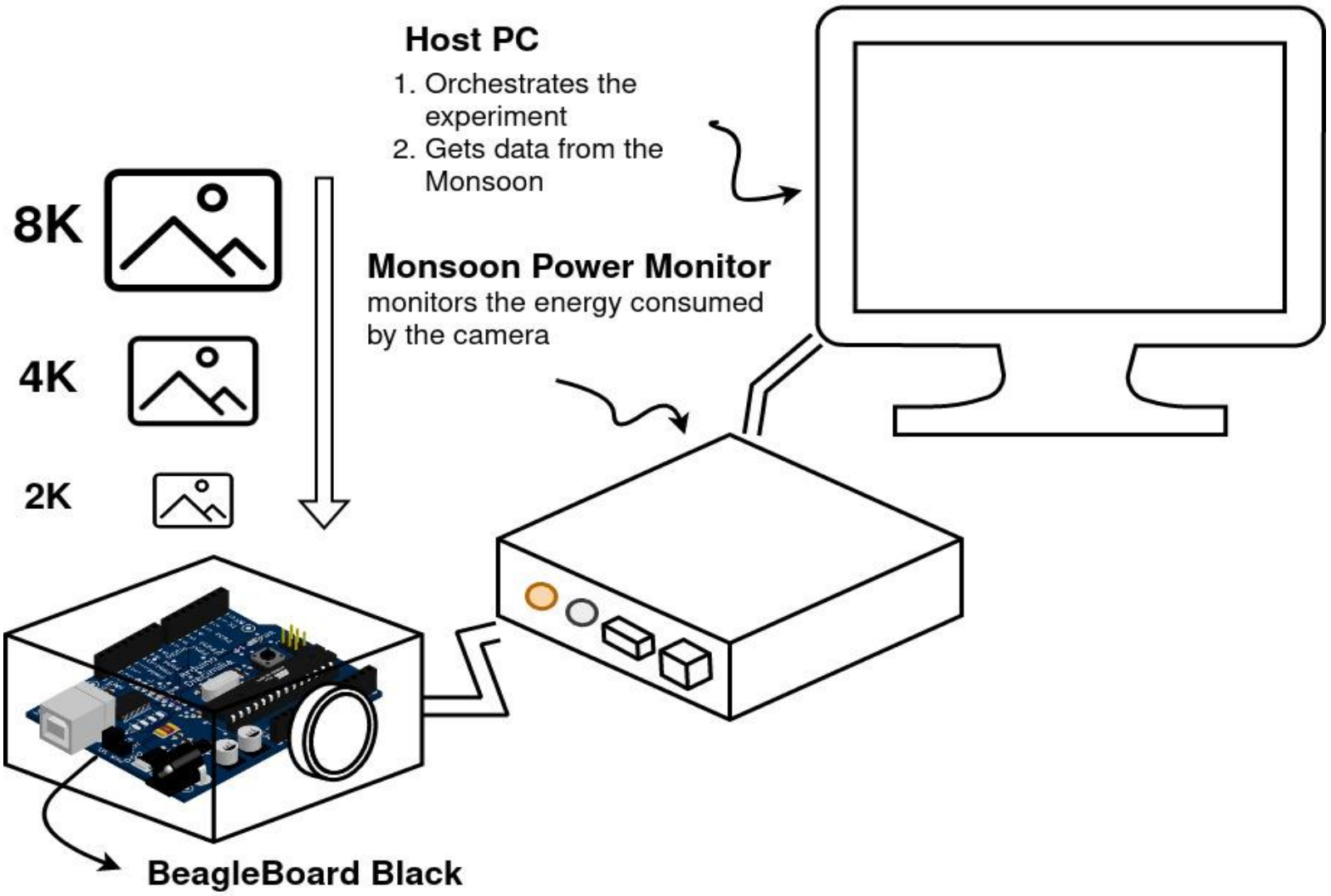
1. to run an experiment where users place orders of 2 or 3 products;
2. to build a performance model approximating the behavior of the system;
3. to calculate how much Joule/s are consumed by resources (i.e., e value);
4. change model parameters;



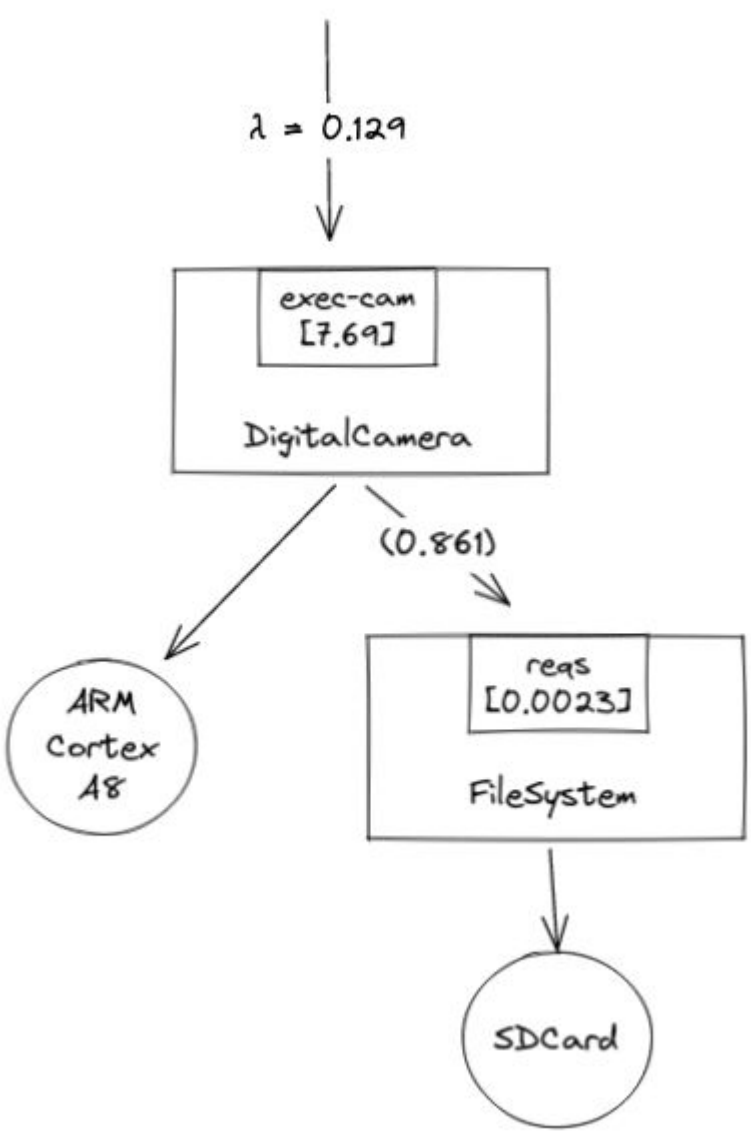
Methodology

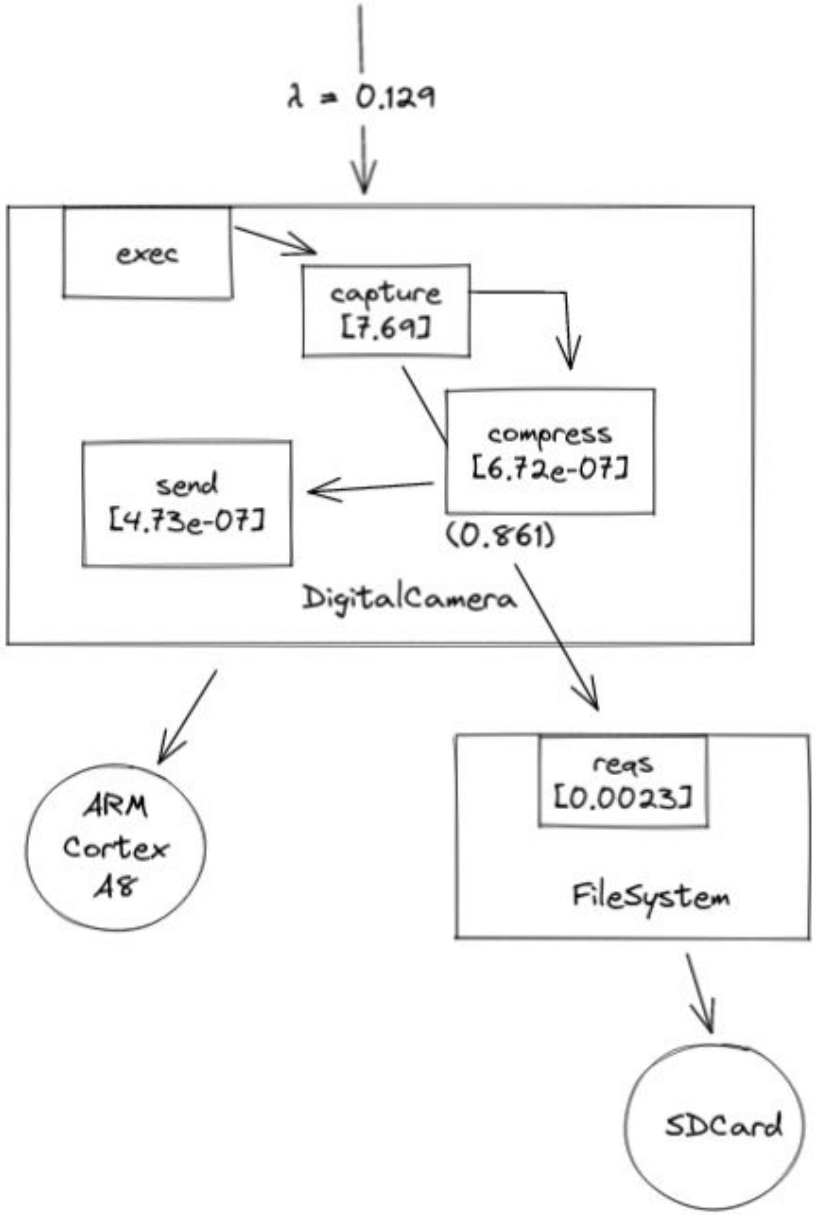


Experimental Setting: Digital Camera

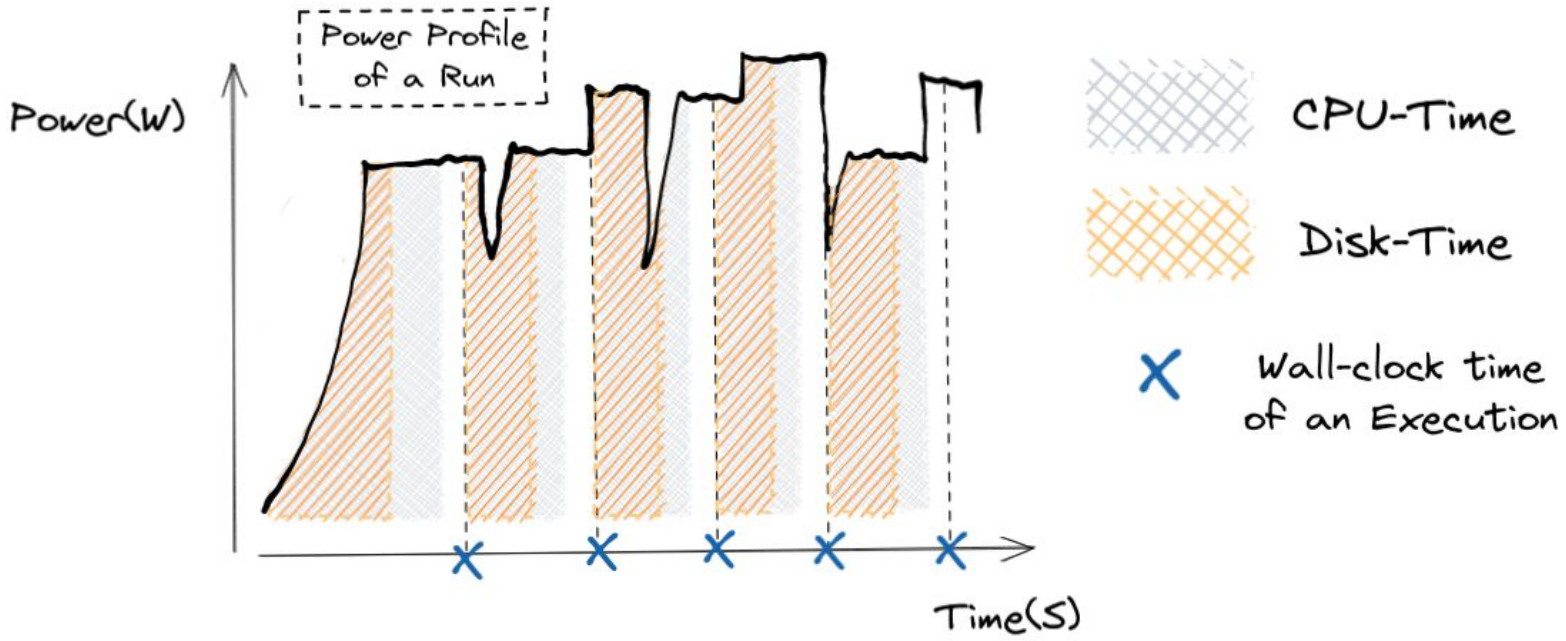


The Layered Queuing Network of the Digital Camera





Energy Consumption Estimation



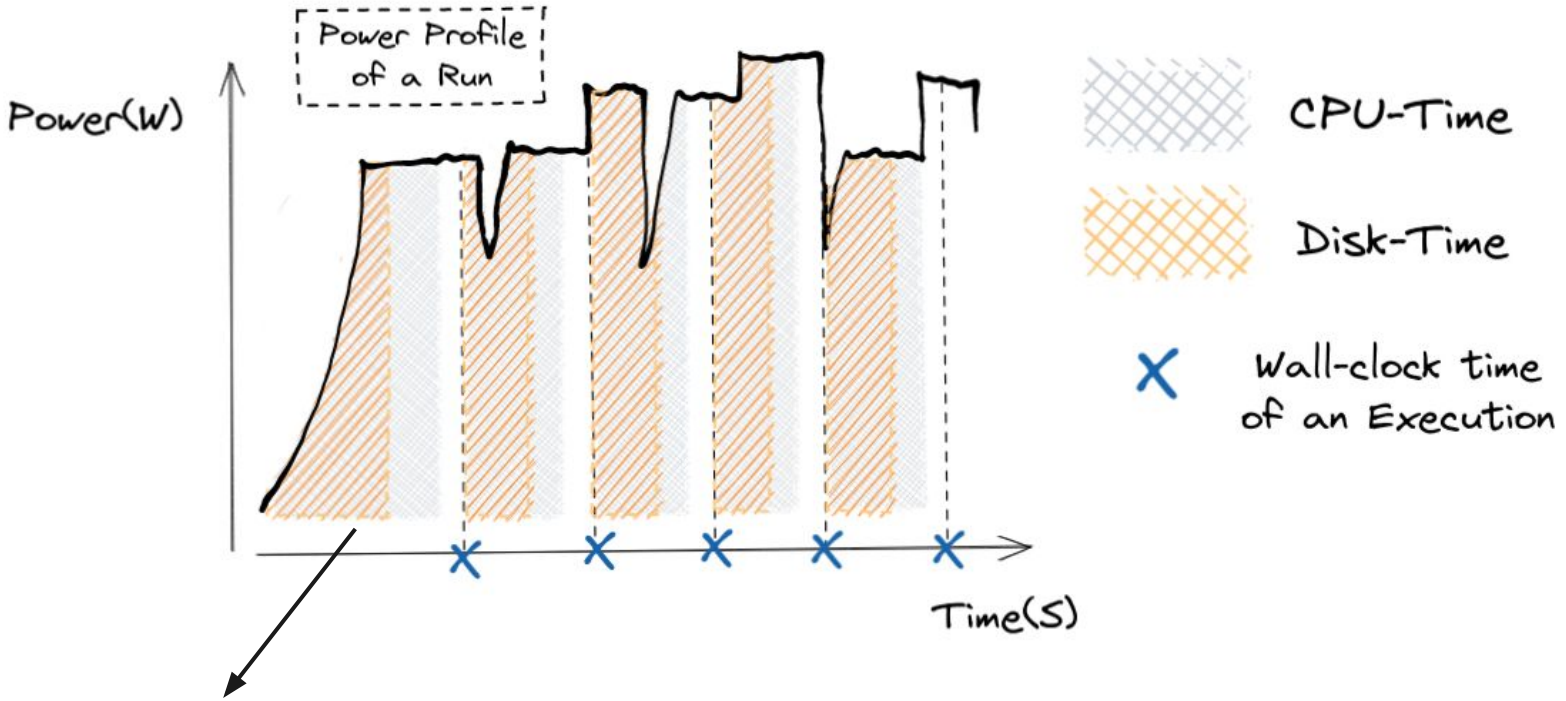
(i) Behavior(Model) ~ Behavior (System)

(ii) ~ is reflexive => Behavior(System) ~ Behavior(Model)

(iii) Behavior => PowerProfile

(iv) PowerProfile(System) ~ PowerProfile(Model)

Energy Consumption Estimation



(1) $$E(res,i) = \int_{t0,i}^{S_{res}} P\,dt[\frac{Joule}{Visit}]$$

(2) $$ED(res) = \sum_{i=1}^{\#Visit} \int_{t0,i}^{S_{res,i}} P\,dt$$

(3) $$E(res) = \frac{ED(res)}{\#Visit}$$

(4) $$e(res) = \frac{E(res)}{S(res)}[\frac{Joule}{s}]$$

Energy Consumption Estimation

$$e(res) = \frac{E(res)}{S(res)}[\frac{Joule}{s}]$$

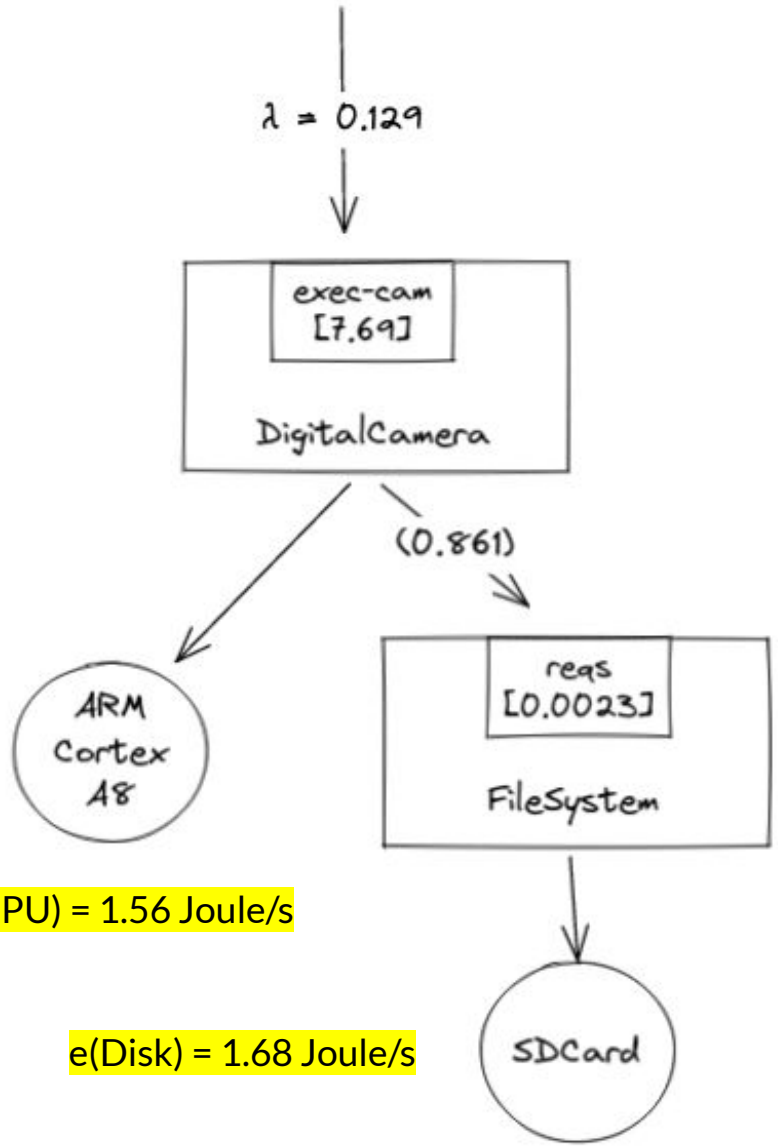
average energy spent per visit

$$E(res) = e(res) \times S(res)$$

The energy per visit when we have a 4K image as input

$$E(CPU) = 1.56 \times 8.0 = 12.48$$

$$ED(CPU) = 12.48 \times 30 = 374.40J$$



e(CPU) = 1.56 Joule/s

e(Disk) = 1.68 Joule/s

Energy Consumption Estimation

➔ the e(res) multiplier varies according to the type of image

Type	Measured	Estimated
2K	93.85	//
4K	381.39	374.40
8K	1530.56	1497.60

Measured and estimated **CPU** energy consumption values

Type	Measured	Estimated
2K	34.35	//
4K	150.35	158.76
8K	591.29	622.94

Measured and estimated **DISK** energy consumption values

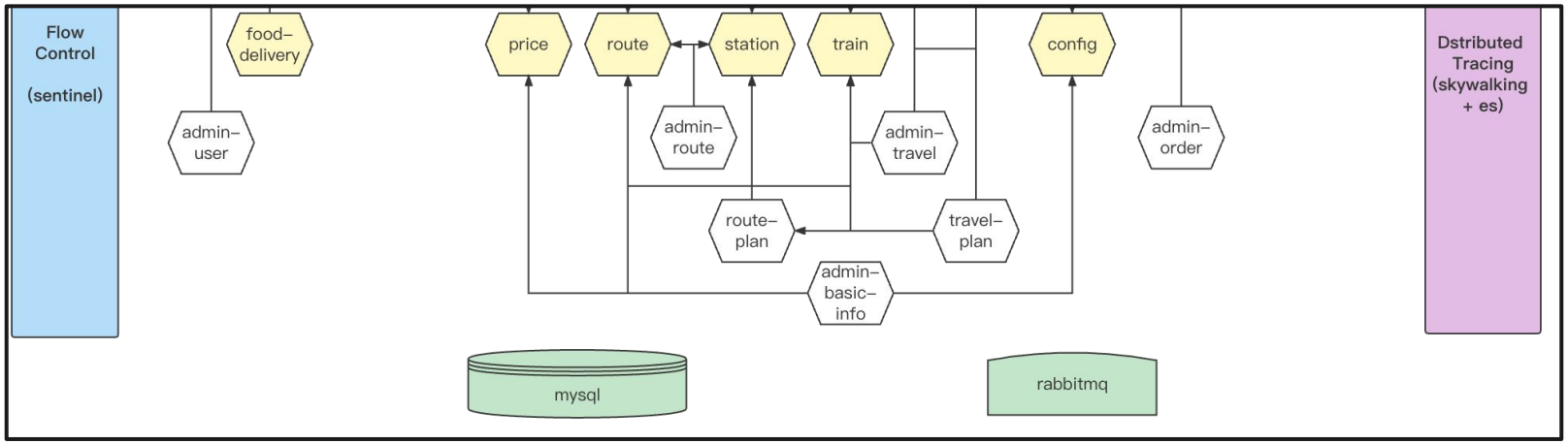
Conclusion

We proposed an improvement of performance models to include energy consumption estimation

- Designers can make informed decisions at design time
- Designers can reduce experimentation time

In the future:

- We need to perform a statistical analysis on the e multiplier
- We are testing the methodology against a more complex case study
  - Train-Ticket Booking System



https://github.com/FudanSELab/train-ticket

References

1. Lotfi Belkhir and Ahmed Elmeligi, *Assessing ICT global emissions footprint: Trends to 2040 & recommendations*, Journal of Cleaner Production, 2018

2. Kyriakos Georgiou, Samuel Xavier-de Souza, and Kerstin Eder. The IoT energy challenge: A software perspective. IEEE Embedded Systems Letters, 2018

3. Kerstin Eder, John P. Gallagher, Pedro Lopez-Garca, Henk Muller, Zorana Bankovic, Kyriakos Georgiou, Remy Haemmerle, Manuel V. Hermenegildo, Bishoksan Kafle, Steve Kerrison, Maja Kirkeby, Maximiliano Klemen, Xueliang Li, Umer Liqat, Jeremy Morse, Morten Rhiger, and Mads Rosendahl.: *ENTRA: Whole-systems energy transparency*, Microprocessors and Microsystems, November 2016

4. Kerstin Eder, *Whole Systems Energy Transparency: More power to software developers!*, Hipeac Summer School, 2021

5. Y. Li et al., *End-to-end energy models for Edge Cloud-based IoT platforms: Application to data stream analysis in IoT*, Future Generation Computer Systems, 2018

Thanks!
Any Questions?