WP7 Extend - control part

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Anna-Lena Ljung
Damiano Varagnolo

This presentation

1. overview of the activities within WP7

2. focus on specific modelling and control problem
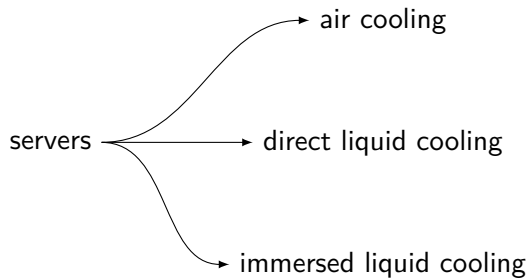
Overview of activities WP7
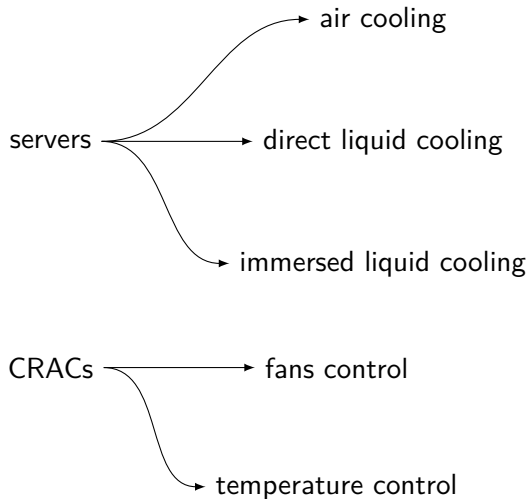
modelling   control
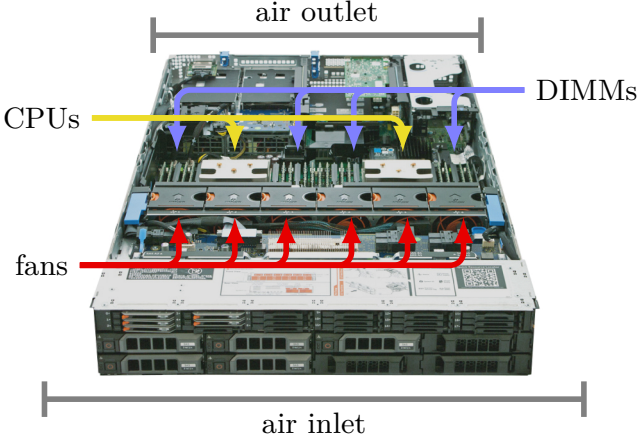
servers   CRACs

Considered technologies
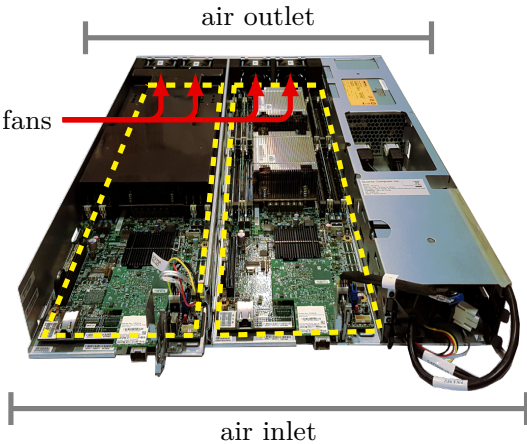

servers
- air cooling
- direct liquid cooling
- immersed liquid cooling

Considered technologies

servers
- air cooling
- direct liquid cooling
- immersed liquid cooling

CRACs
- fans control
- temperature control

brief overview of where we are
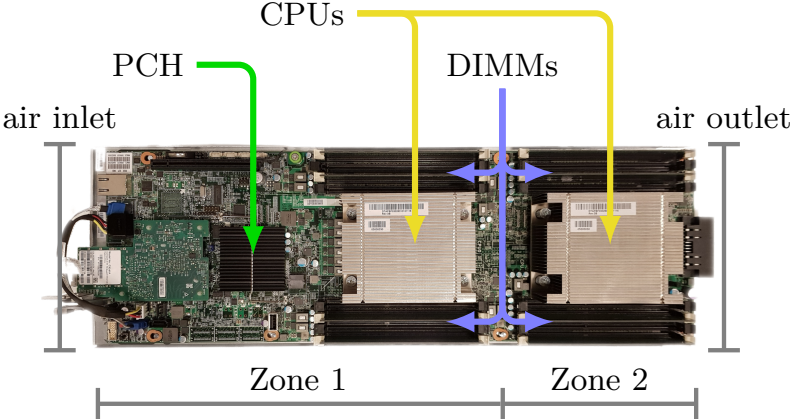
Air cooled servers

air outlet

DIMMs

CPUs

fans

air inlet

Air cooled servers

Air cooled servers

Air cooled servers

Research path

Air cooled servers

general physics based models accounting also for chip's losses

Air cooled servers

general physics based models accounting also for chip's losses

↳ strategies for identifying the models from field data

Air cooled servers

general physics based models accounting also for chip's losses

strategies for identifying the models from field data

MPC strategies tailored for our polynomial models

Air cooled servers

general physics based models accounting also for chip's losses

strategies for identifying the models from field data

MPC strategies tailored for our polynomial models

extensive field tests with open-compute servers

Air cooled servers

general physics based models accounting also for chip's losses

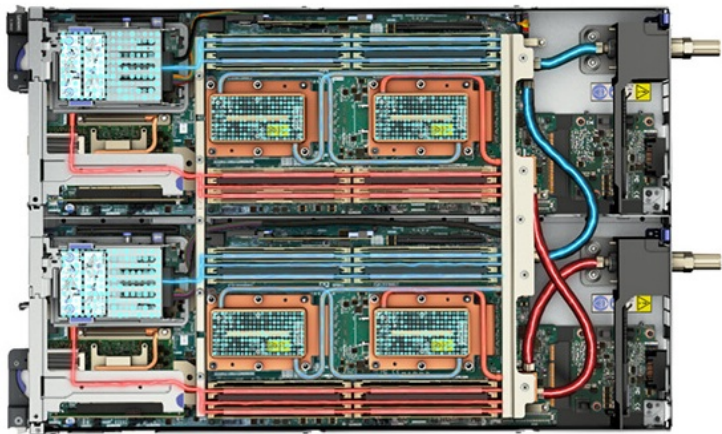strategies for identifying the models from field data

MPC strategies tailored for our polynomial models

extensive field tests with open-compute servers

better-than-expected results with consequences on how to manage the CRACs

Servers with direct liquid cooling

Servers with direct liquid cooling

general physics based models accounting for fluid dynamics effects

*(connected in several ways with the air-cooling models)*

Servers with direct liquid cooling

Research path

general physics based models accounting for fluid dynamics effects
(connected in several ways with the air-cooling models)

↳ strategies for identifying the models from field data

↳ MPC strategies tailored for our polynomial models

field tests with open-compute servers:
should start in July / August

Immersed liquid cooling vessels

setups
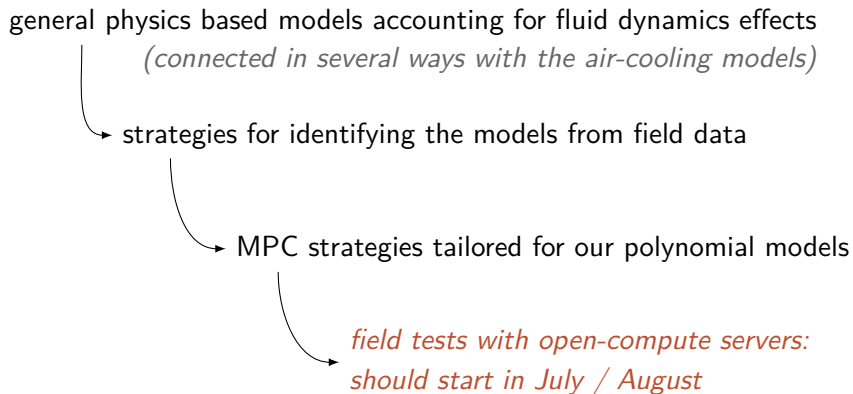
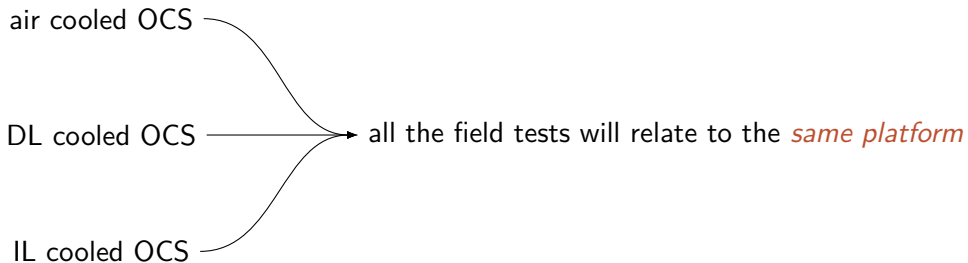"single server"   "pool of servers"
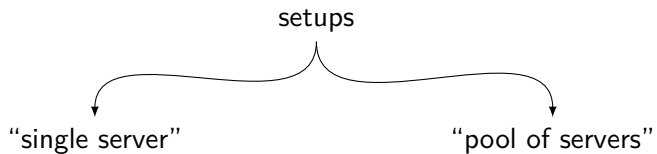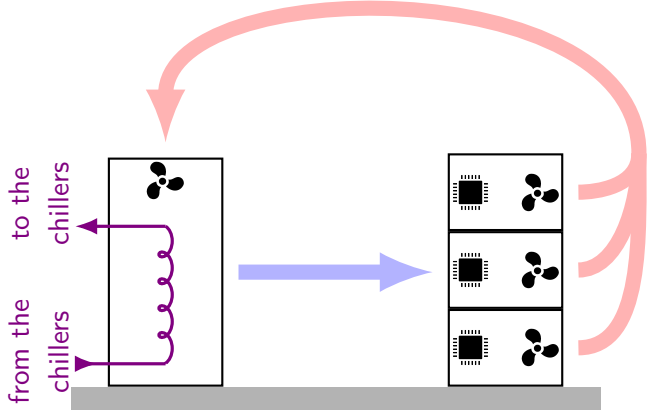
Immersed liquid cooling vessels - TODOs

- control-oriented models *(not yet developed)*
- control strategies *(not yet developed)*
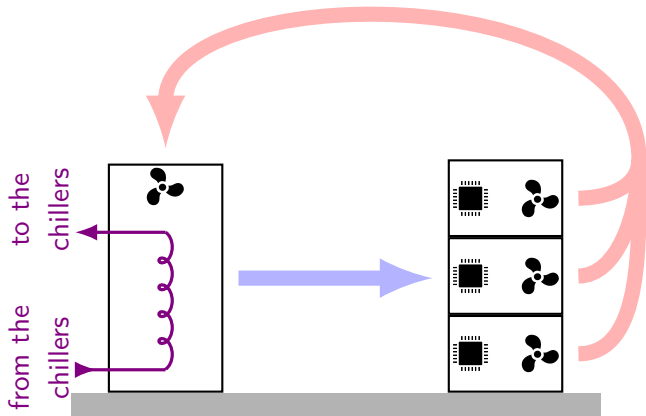- measurement campaigns *(started this week)*

summary of the "servers side":

developed (but still developing) a grasp for the problem

Side note on the "servers side"

air cooled OCS

DL cooled OCS ——————> all the field tests will relate to the *same platform*

IL cooled OCS

to the chillers

from the chillers

first problem: CRACs temperature control

CRACs temperature control

identified some data-driven based models

↳ derived preliminary PID and LQR strategies

↳ did preliminary field tests on Pod 2

↳ *saw savings potentials . . .*

CRACs temperature control

identified some data-driven based models

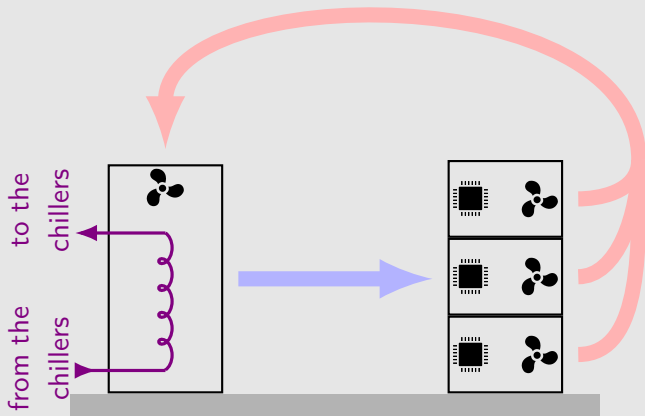↪ derived preliminary PID and LQR strategies

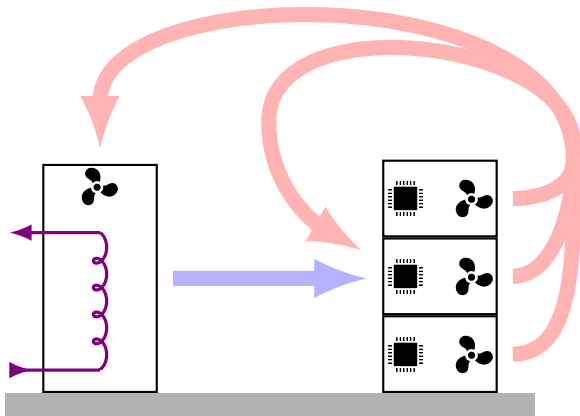↪ did preliminary field tests on Pod 2

↪ *saw savings potentials . . .*
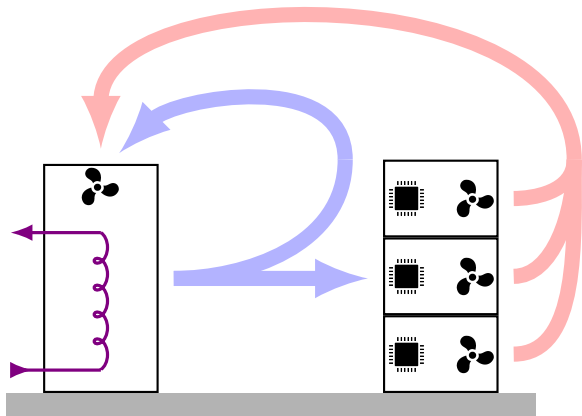*. . . but also phenomena suggesting to control also the fans speed!*

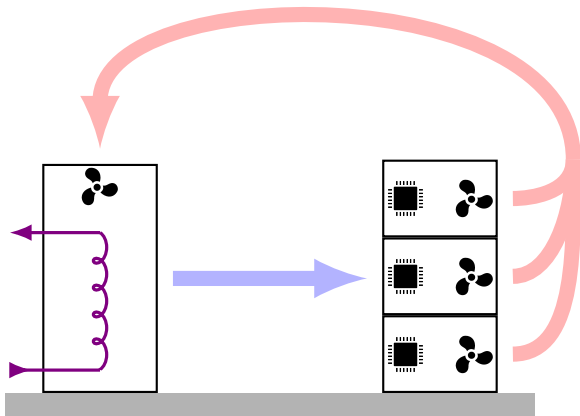today's discussion: CRACs fans control

Intuitions: underprovisioning

Intuitions: overprovisioning

Intuitions: correct provisioning

What are the implications?

- non-correct provisioning $\implies$ mixing fluxes

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- underprovisioning $\implies$ the servers receive also some exhaust

What are the implications?

- non-correct provisioning $\implies$ mixing fluxes

- overprovisioning $\implies$ cool the exhaust before it enters in the CRAC $\implies$ use the CRAC fans more than necessary

- underprovisioning $\implies$ the servers receive also some exhaust $\implies$ have a higher inlet temperature (i.e., potential thermal discomfort plus disturbing the temperature control system)

question: is air-tightness always guaranteed?

Slight diversion: how are the CRACs' fans controlled today?
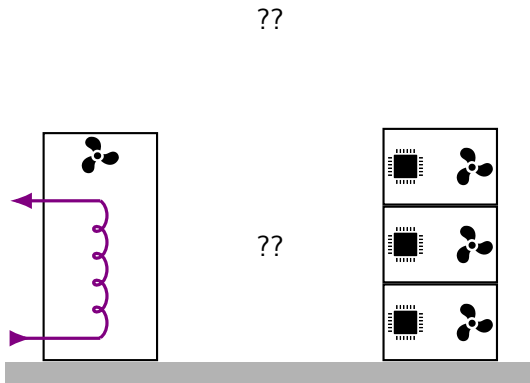
industrial standard =
    select the fans speed given the nominal DC's working point & keep it constant

2nd question: is keeping the CRACs' fans speed constant a good idea?

Chain of implications

- being in a correct / underprovisioning / overprovisioning regime depends on the servers fans speeds
  (i.e., on total effective air resistance within the room)

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- but servers fans speeds depend on servers temperatures and servers temperatures depend on IT loads

Chain of implications

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  (i.e., on total effective air resistance within the room)

- but servers fans speeds depend on servers temperatures and servers temperatures depend on IT loads

- IT loads change in time $\implies$ regimes change in time

CRACs' fans control problem = react to non-correct provisioning situations

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1st requirement: detect if the provisioning is not correct

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problem: creating models from blueprints or CFD simulations is not feasible
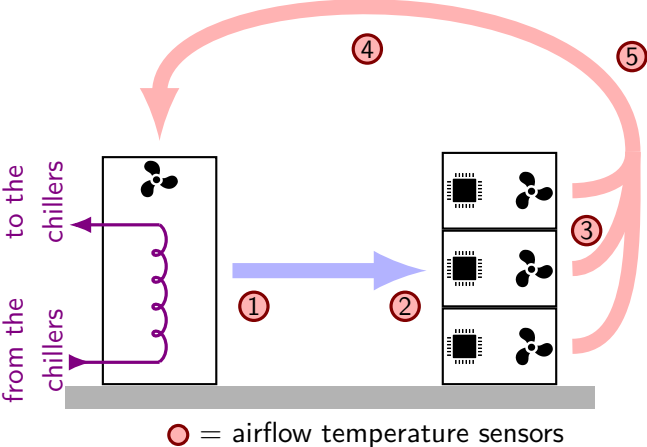
CRACs' fans control problem = react to non-correct provisioning situations

1st requirement: detect if the provisioning is not correct

problem: creating models from blueprints or CFD simulations is not feasible

$\implies$ solution = data driven air-flow provisioning models

Where shall we put the sensors?

$\bigcirc$ = airflow temperature sensors

Our (latest) contribution

Intuitions- and experience-driven methodology to:

- put the sensors in the right places, plus
- find data driven models for the phenomena above, plus
- develop the fans control algorithms

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Detecting and modelling air flow overprovisioning / underprovisioning in air-cooled datacenters

Emanuele Simonazzi[*], Miguel Ramos Galrinho[†], Damiano Varagnolo[‡], Jonas Gustafsson[§], Winston Garcia-Gabin[¶]

</div>

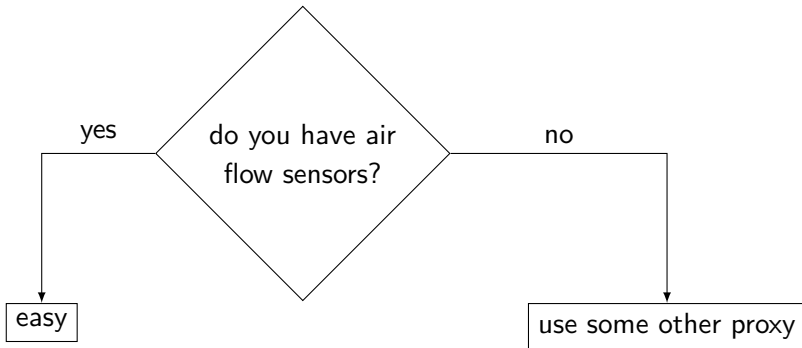# How can we detect incorrect air provisionings? (intuitions)

do you have air
flow sensors?

How can we detect incorrect air provisionings? (intuitions)
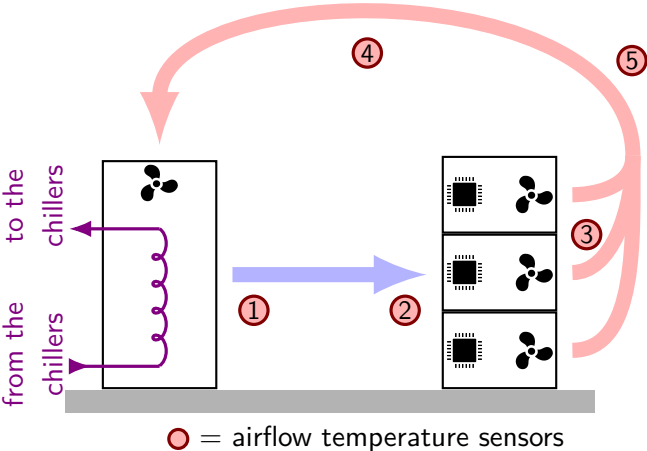

do you have air
flow sensors?

yes

easy
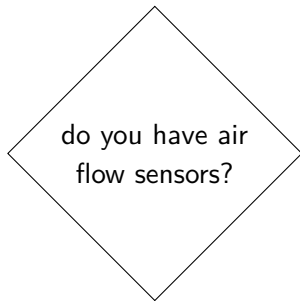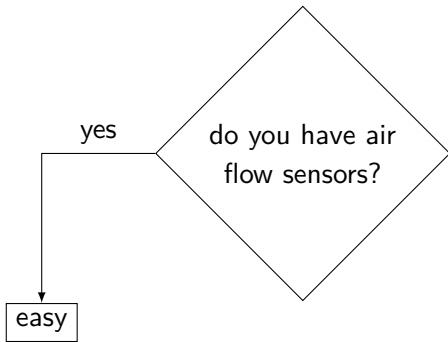
(do you really have them?)

How can we detect incorrect air provisionings? (intuitions)

yes ← do you have air flow sensors? → no

easy

(do you really have them?)

use some other proxy

How can we detect incorrect air provisionings? (intuitions)

do you have air flow sensors?

yes → easy

(do you really have them?)

no → use some other proxy

intuition: flows mixings $\implies$ temperature mixings

Shall we measure T or ΔT?

○ = airflow temperature sensors
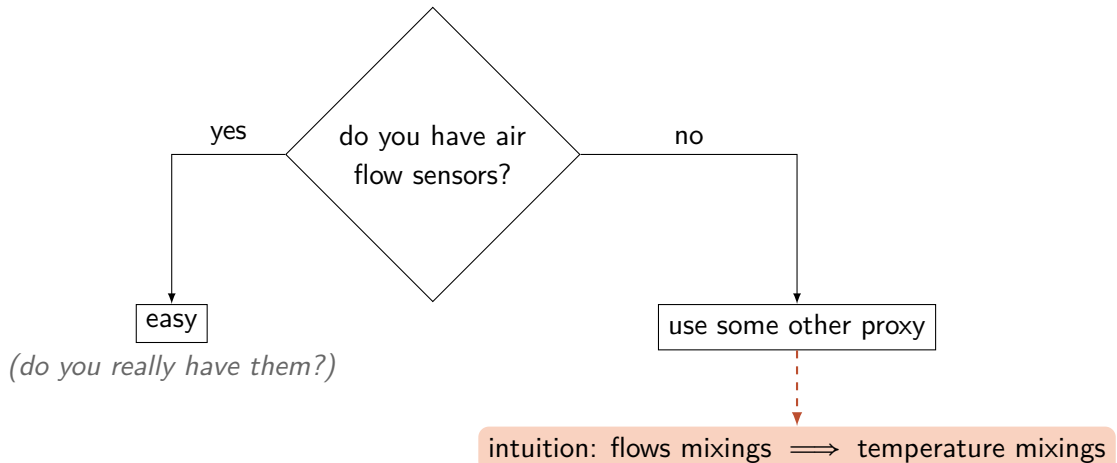
Example from the IECON paper
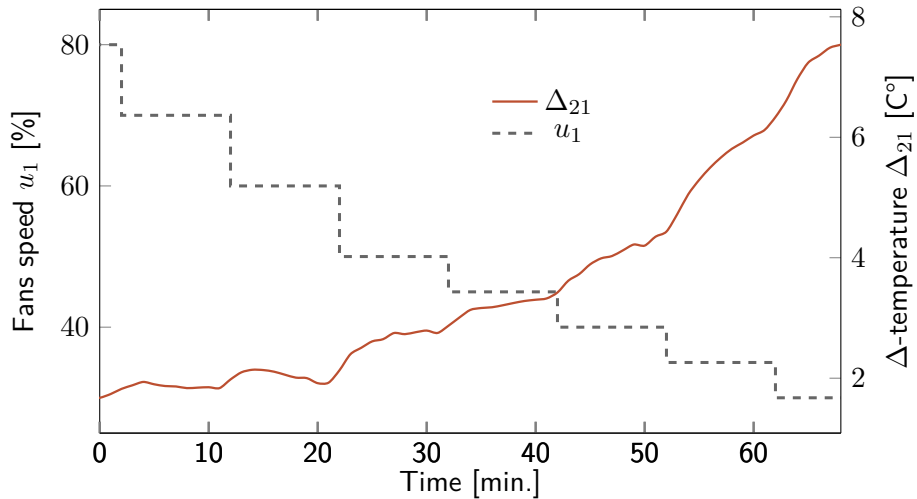
Summary

- gained expertise at the servers level
- gaining expertise at the CRACs level

Future steps:

- combine the temperature control and the fans control of the CRACs
- cascade the CRACs control with the local servers fans control

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