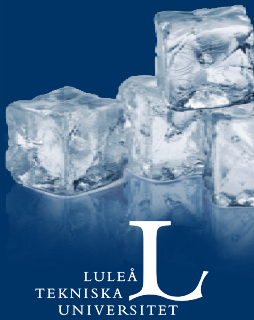
Skandinaviens nordligaste tekniska universitet
Forskning & utbildning i världsklass

Datacenters control: challenges and opportunities

Damiano Varagnolo, PhD



Thanks to. . .

Thanks to. . .


ABB


ERICSSON


Swegon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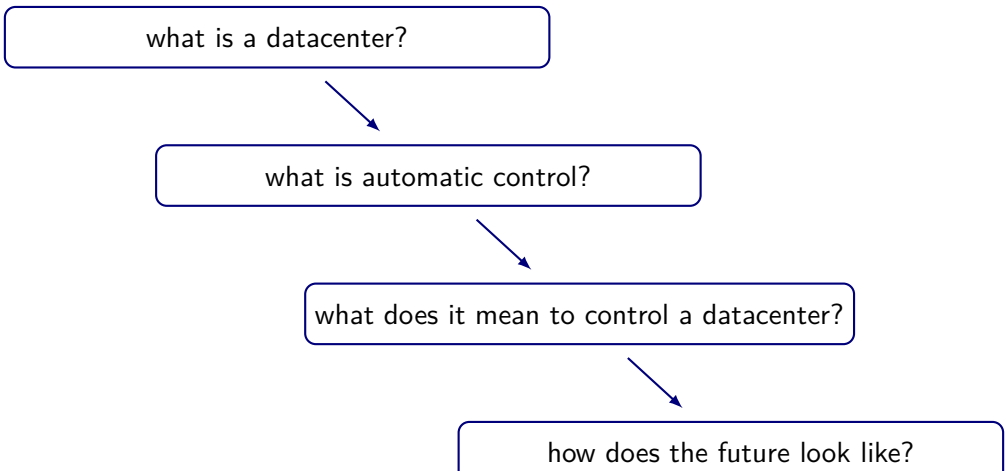
Bodens kommun


eltic-Plus
Smart Connected World

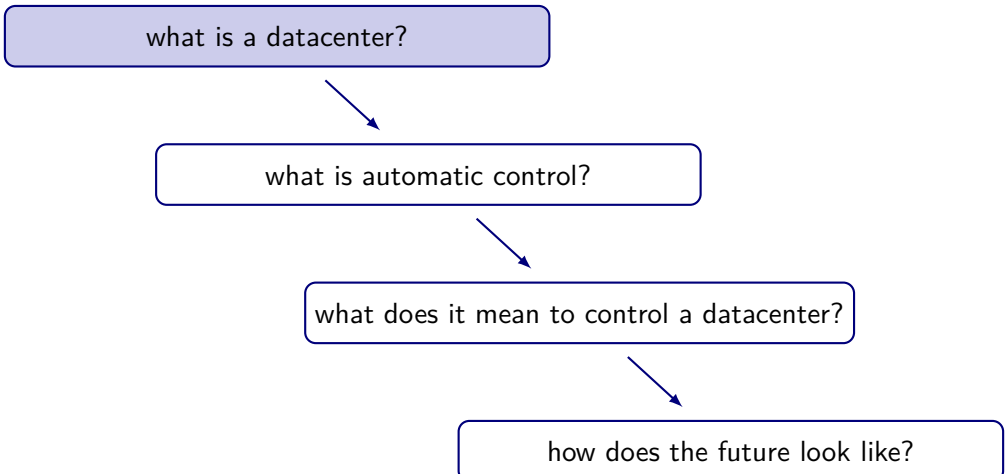

Energimyndigheten


VINNOVA

Roadmap


what is a datacenter?
what is automatic control?
what does it mean to control a datacenter?
how does the future look like?

Roadmap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What is a datacenter?

"a facility that centralizes an organization's IT operations and equipment, and where it stores, manages, and disseminates its data"

 Google (Apr. 2017)

What is a datacenter?

TierPoint datacenters, Dallas

What is a datacenter?

Facebook, Luleå, Sweden

What is a datacenter?

Sun Microsystems Modular Datacenter

Why do they exist?

- lower delays and high bandwidth between the servers
- easier to maintain
- higher level of data security and privacy

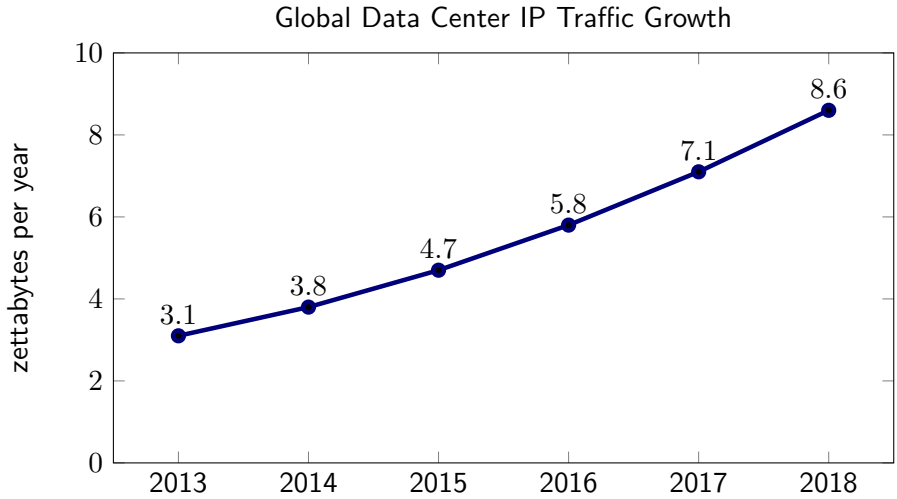
What is their footprint?

In 2013 for EU-28:

- electrical energy consumption: 103.4 GWh
  ($\sim 3\%$ of the total generation)
- industry market: 18.85 billion €
- CO_2 emissions: 38.6 million tonnes (347g/kWh)

Pan European Datacenter Academy Project (2014)
Final Report Summary

What will their footprint be?



Cisco Global Cloud Index 2013 - 2018

What will their footprint be?

"forecasted energy savings from implementing ***best practices*** in datacenters in EU is 15,500GWh per year, approximatively equivalent to the energy consumed by 1M EU households yearly, 1.1 billion euro in electricity costs, 5.4 Mtonnes of CO_2"

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Final Report Summary

The best practices

- Optimize Air Management
- Right-Size the Design
- Optimize the Central Plant
- Design Efficient Air Handling
- Improve Humidification Systems and Controls
- Specify Efficient Power Supplies
- Consider On-Site Generation
- Employ Liquid Cooling
- Reduce Standby Losses
- Improve Design, Operations, and Maintenance Processes

Best Practices for Data Centers: Lessons Learned from Benchmarking 22 Data Centers
Greenberg et al. (2006)
ACEEE Summer Study on Energy Efficiency in Buildings

The best practices & Automatic Control

- *Optimize Air Management*
- Right-Size the Design
- *Optimize the Central Plant*
- Design Efficient Air Handling
- *Improve Humidification Systems and Controls*
- Specify Efficient Power Supplies
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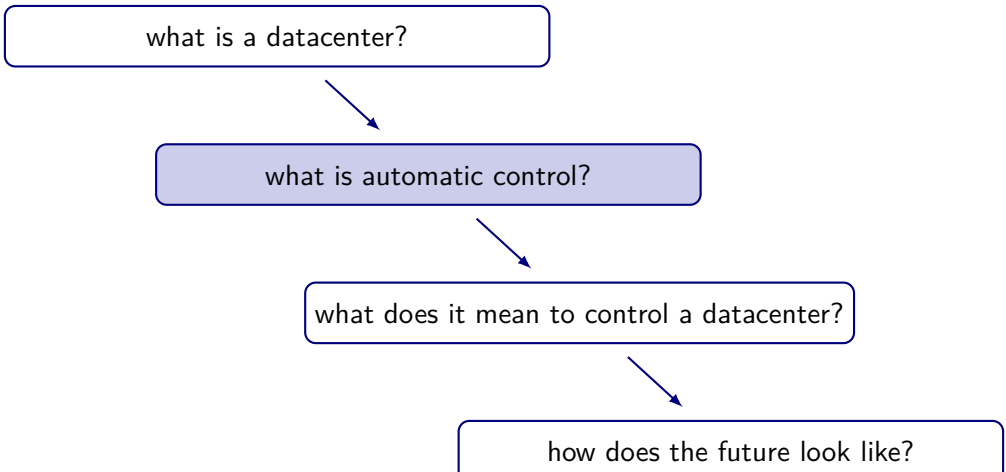
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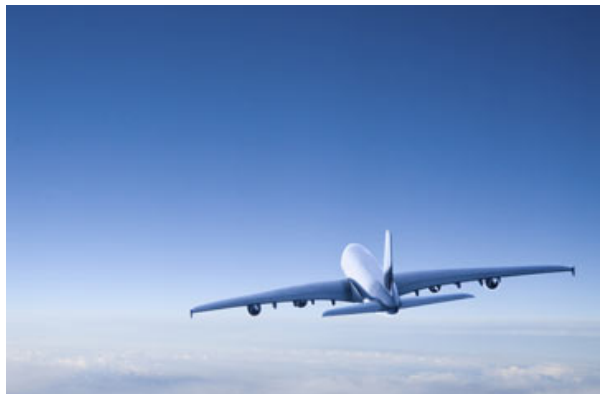
What is automatic control?

"the application of mechanisms to the operation and regulation of processes without continuous direct human intervention"

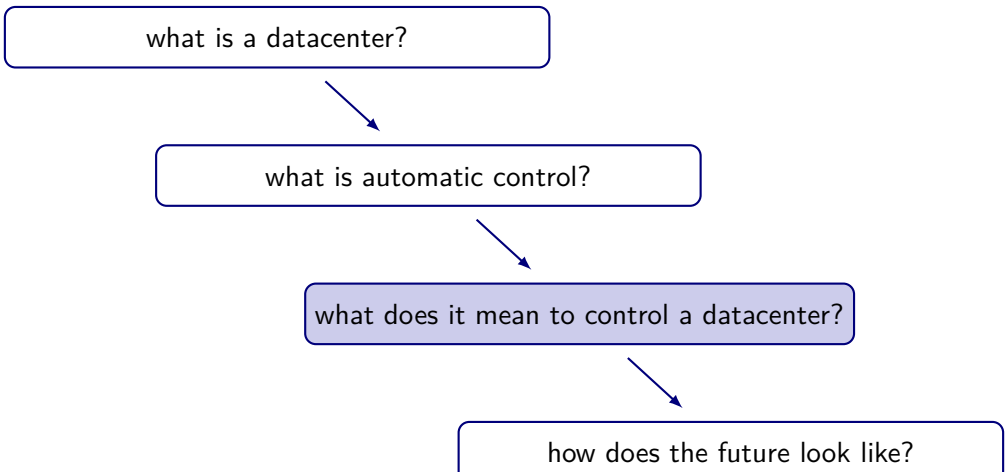
 Wikipedia (Apr. 2017)

Example



readings from the sensors → automatic control algorithms → commands to the motors and flaps

Roadmap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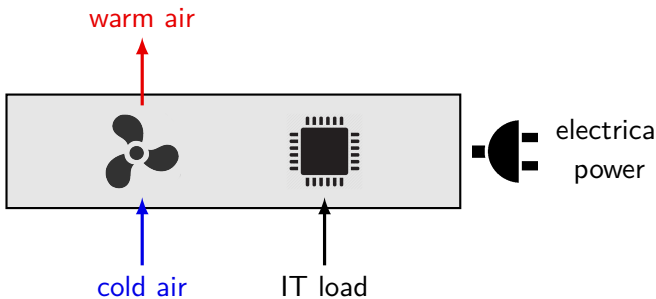
Control perspectives on a single server



Control perspectives on a single server

Control problem

Control aim

- maximize IT QoS + minimize electric consumptions

Inputs

Controllable:

- CPUs frequencies
- number of VMs
- fan speed

Non-controllable:

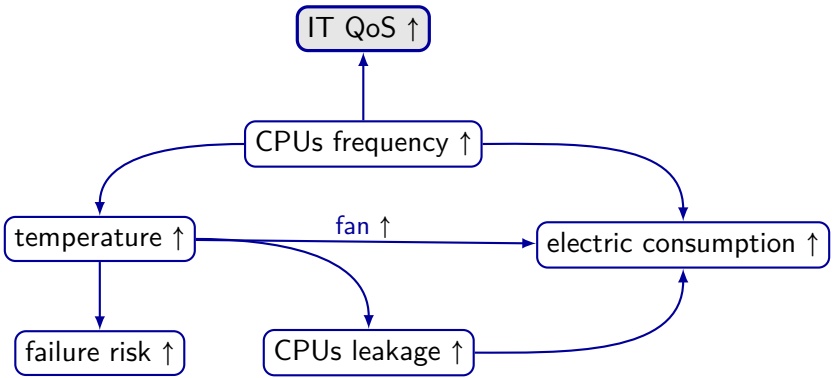
- IT load

Disturbances

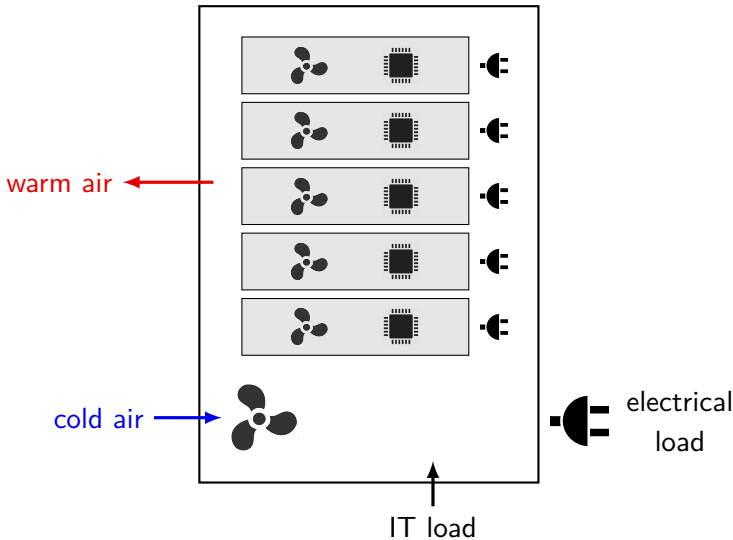
- temperature of the air inlet

Control perspectives on a single server

Hints on the dynamics



Control perspectives on a servers rack



Control perspectives on a servers rack

Control problem

Control aim

- maximize IT QoS + minimize electric consumptions

Inputs

Controllable:

- CRAC fans speed
- servers & VMs ON / OFF
- IT loads assignment

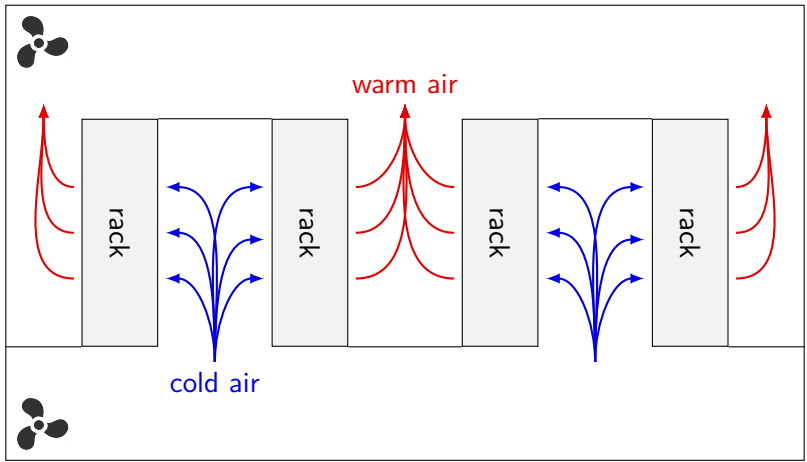
Non-controllable:

- IT load

Disturbances

- temperature of the air inlet
- thermal couplings

Control perspectives on a whole datacenter



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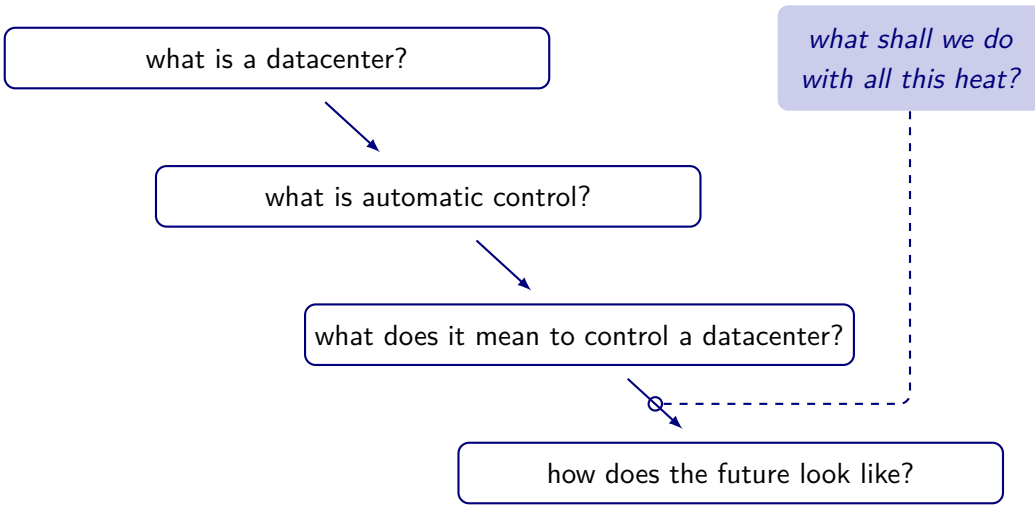
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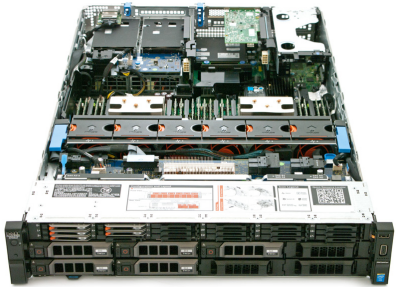
what shall we do with all this heat?

Heat recovery

technologies:

air cooled

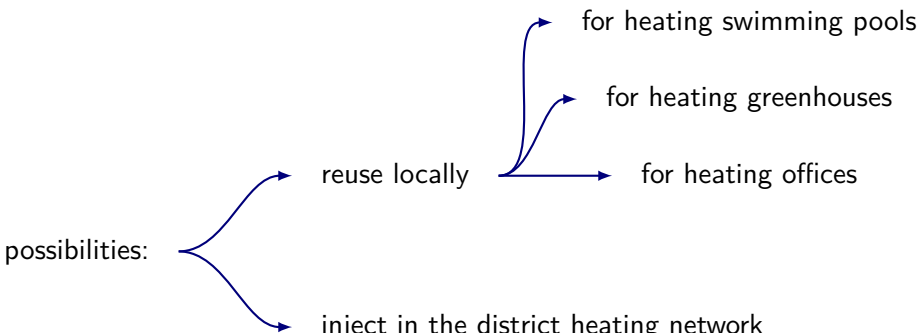


liquid cooled

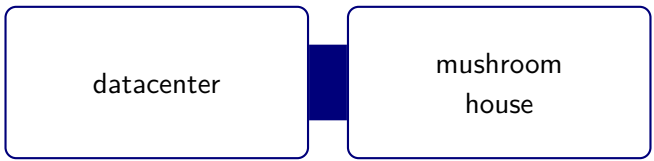
Water-Cooled IBM BladeCenter QS22

Credit: IBM Research – Zurich

Heat recovery



Green Power: growing mushrooms with datacenters



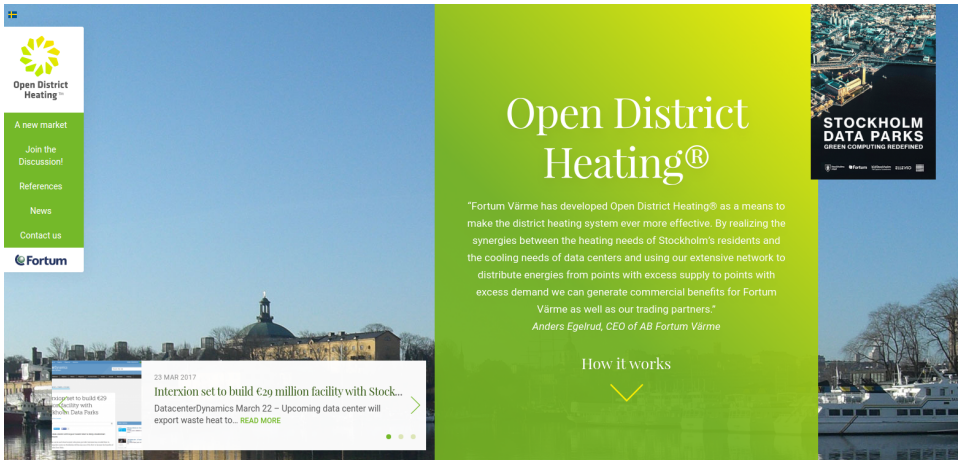
- towards food independence
- less usage of land, fertilizers and pesticides
- usable in pharmaceuticals & as health promoter
- way of reusing local forest residues & other biowastes
- useful for bioconversion processes (e.g., ethanol production)

Green Power: growing mushrooms with datacenters

Green Power: growing mushrooms with datacenters

in collaboration with SLU

Fortum's *Open District Heating* initiative



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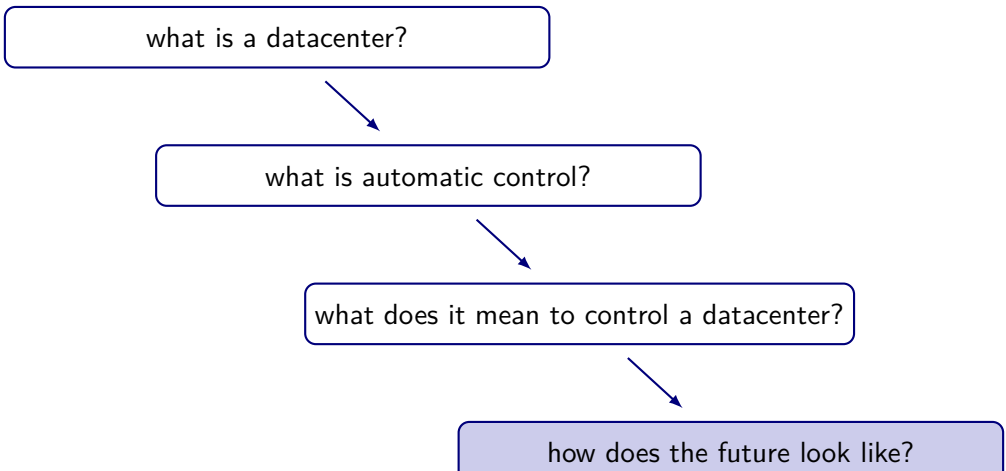
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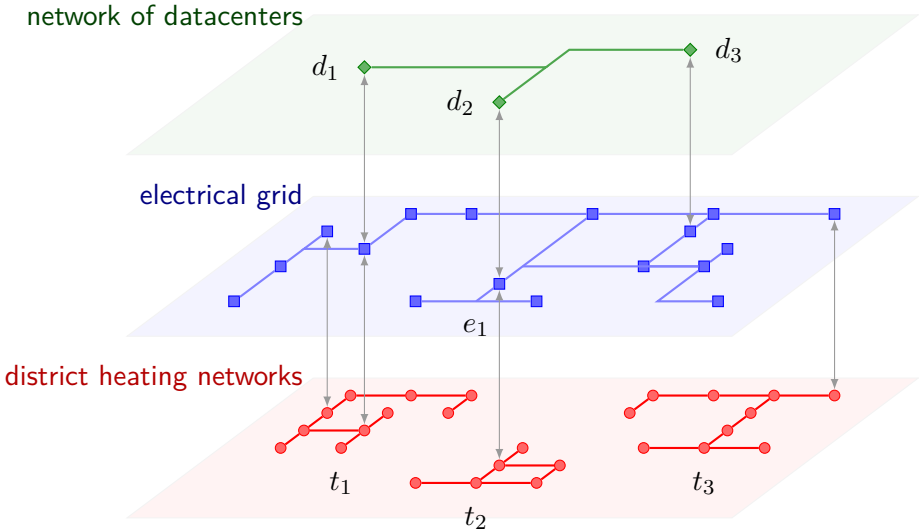
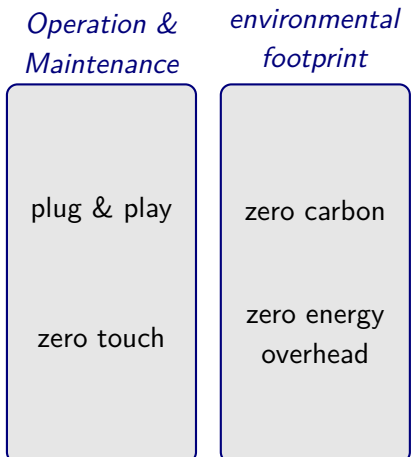
Datacenters = bridges between electrical and thermal grids



Current research directions



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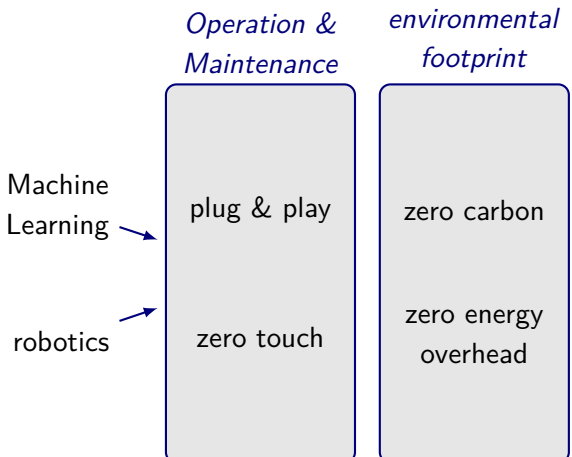

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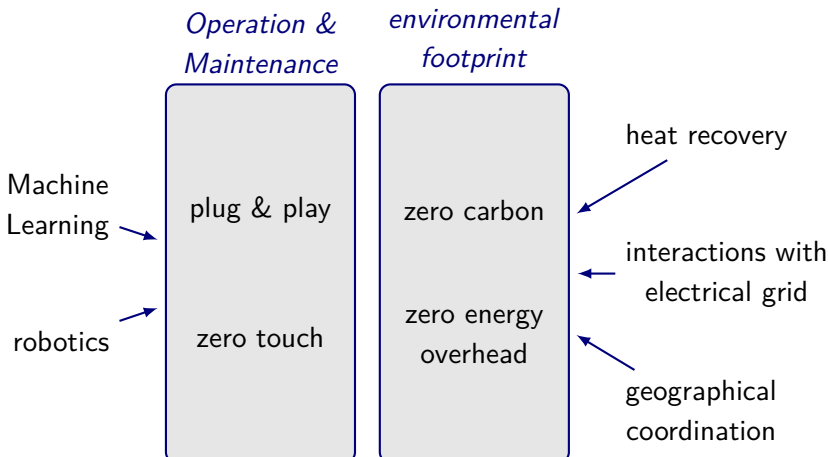
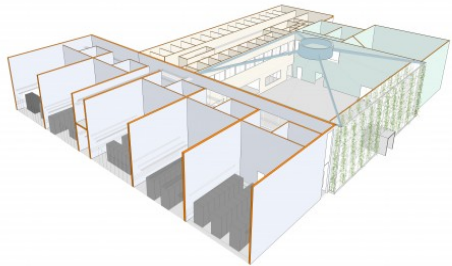
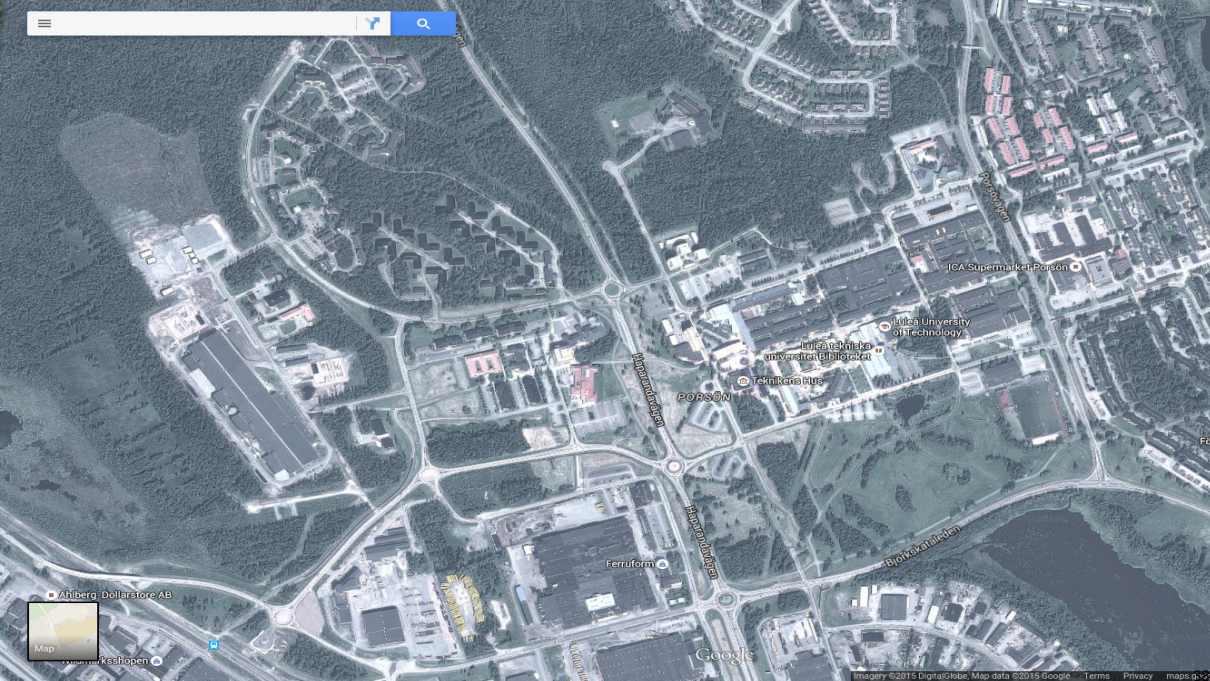


the SICS ICE testbed

The SICS ICE datacenter

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ICA Supermarket Porsön
Luleå University of Technology
Luleå tekniska universitet Biblioteket
Teknikens Hus
PORSÖN
Hägerströmsvägen
Hägerströmsvägen
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Privacy

The SICS ICE datacenter

Characteristics

- 3000 - 4000 servers (2MW)
- 160 m^2 lab
- biogas back up generators
- connections with the urban district heating network
- Generality, Flexibility and Expandability

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Experiment-as-a-Service

In conclusion

- big “market”, even bigger in the future

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- reusing heat is a societal need

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- big “market”, even bigger in the future
- reusing heat is a societal need
- handling the energy flows within and from the datacenters needs advanced control strategies

Data centers control: challenges and opportunities

Damiano Varagnolo

Luleå University of Technology

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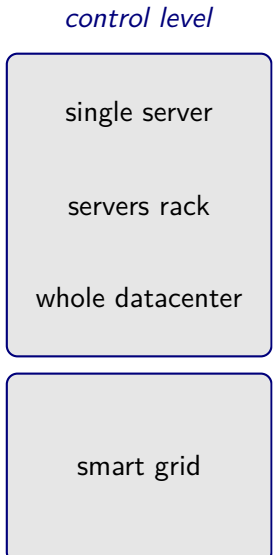
References

Appendix 1: ASHRAE recommended and allowable ranges for temperature and humidity

ASHRAE TC 9.9 Mission Critical Facilities, Technology Spaces and Electronic Equipment

	Recommended	Allowable
Temperature Range	18-27C	10-35C
Moisture Range	5.5C DP or 60 %RH	20-80 %RH

Appendix 2: state of the practice in the control framework



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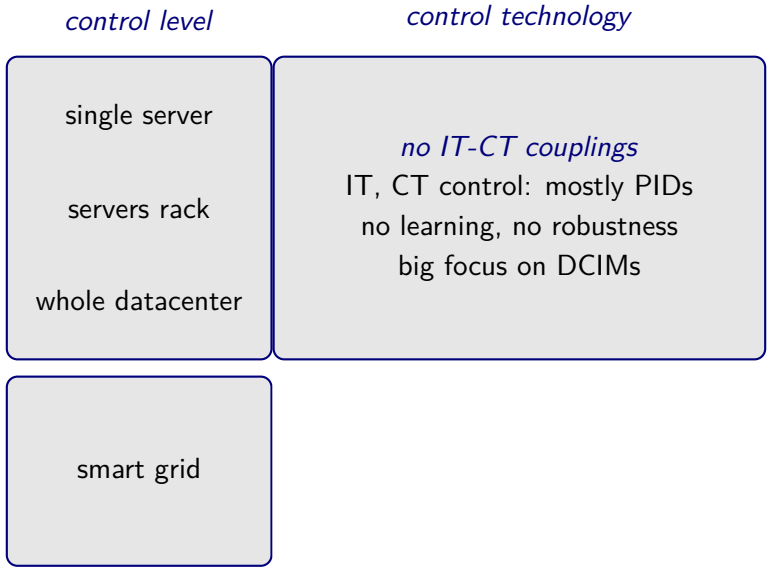
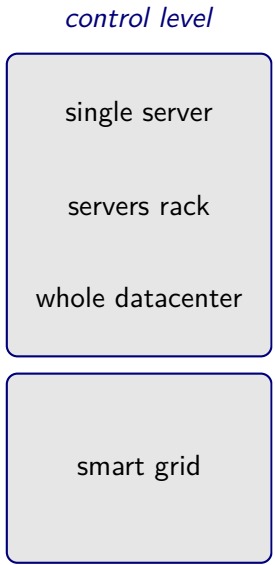


Appendix 2: state of the practice in the control framework

control level	*control technology*
single server servers rack whole datacenter	*no IT-CT couplings* IT, CT control: mostly PIDs no learning, no robustness big focus on DCIMs
smart grid	some experiments on demand response and district heating integration

Appendix 2: state of the art in the control framework



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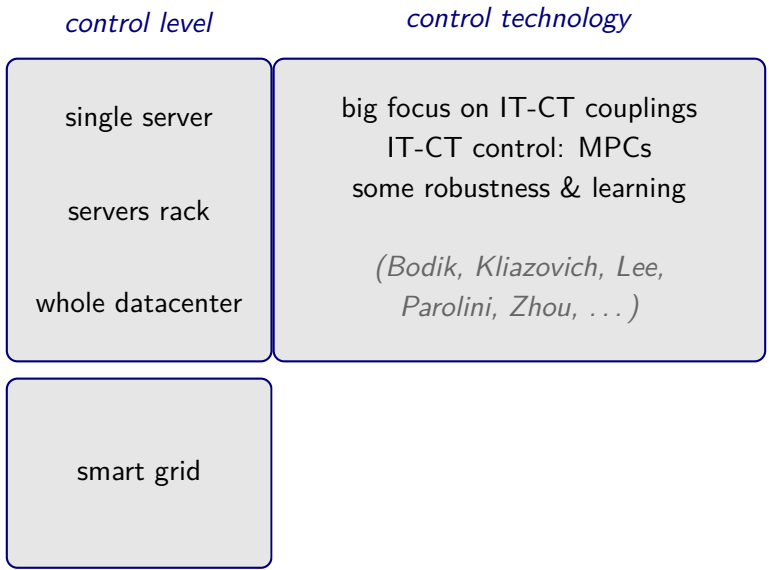

Appendix 2: state of the art in the control framework

control level	*control technology*
single server servers rack whole datacenter	big focus on IT-CT couplings IT-CT control: MPCs some robustness & learning *(Bodik, Kliazovich, Lee, Parolini, Zhou, . . .)*
smart grid	load shedding geographical load balancing integration with renewables