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TRANSCEND Strategic action

FNSNF

Holistic Thermal-Aware Design for Energy-Minimal Datacenters

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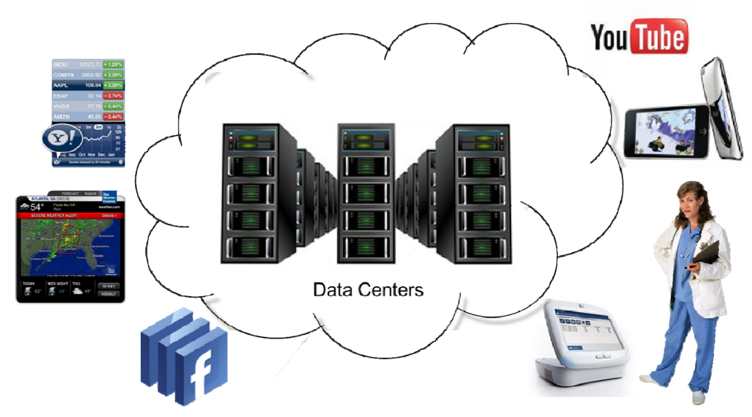
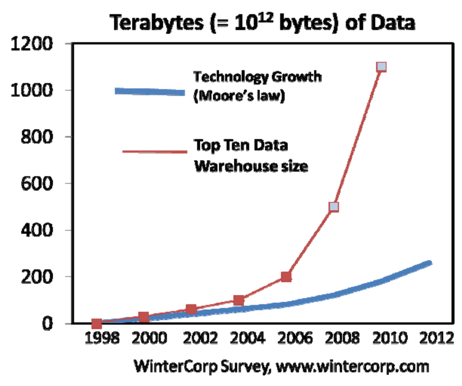
ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE · ESL · PARALLEL SYSTEMS ARCHITECTURE LAB · LTCM · BRAIN SERVE PURE DATACENTER · ETH zürich · Computer Engineering and Networks Laboratory TIK · CREDIT SUISSE

Premises and Action Motivation

- IT services are becoming indispensable for proper operation of our modern digital world
  1. To access information
  2. To process large-scale data sets
- → Datacenters represent the foundations of our IT society's infrastructure

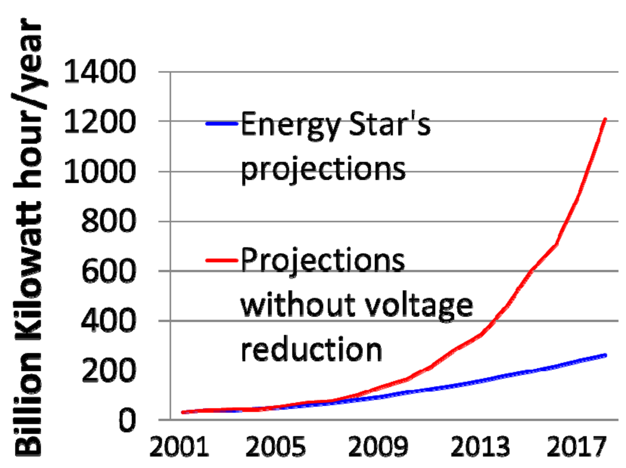


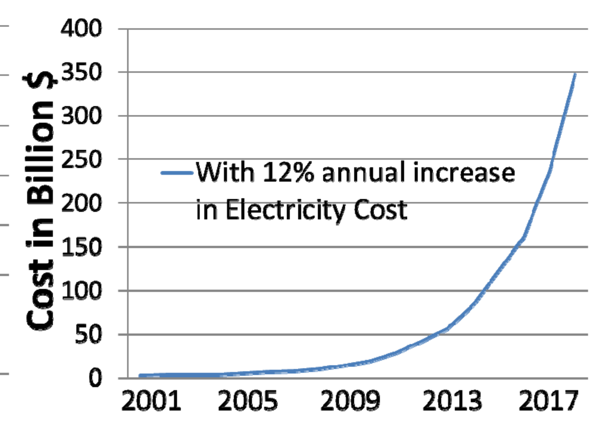
- Demand for data computing has grown faster than technology can sustain
- → Datacenters are hitting fundamental technological barriers:
  1. Energy-scalability wall in computing systems
  2. Poor power efficiency in datacenter

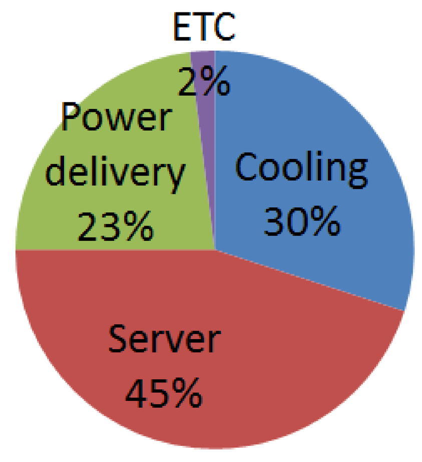


Energy Crisis in Datacenters

- Datacenter operation will require soon more money per year for energy costs than for IT equipment replacement
- *→ Drastic improvements in datacenter power efficiency needed!*



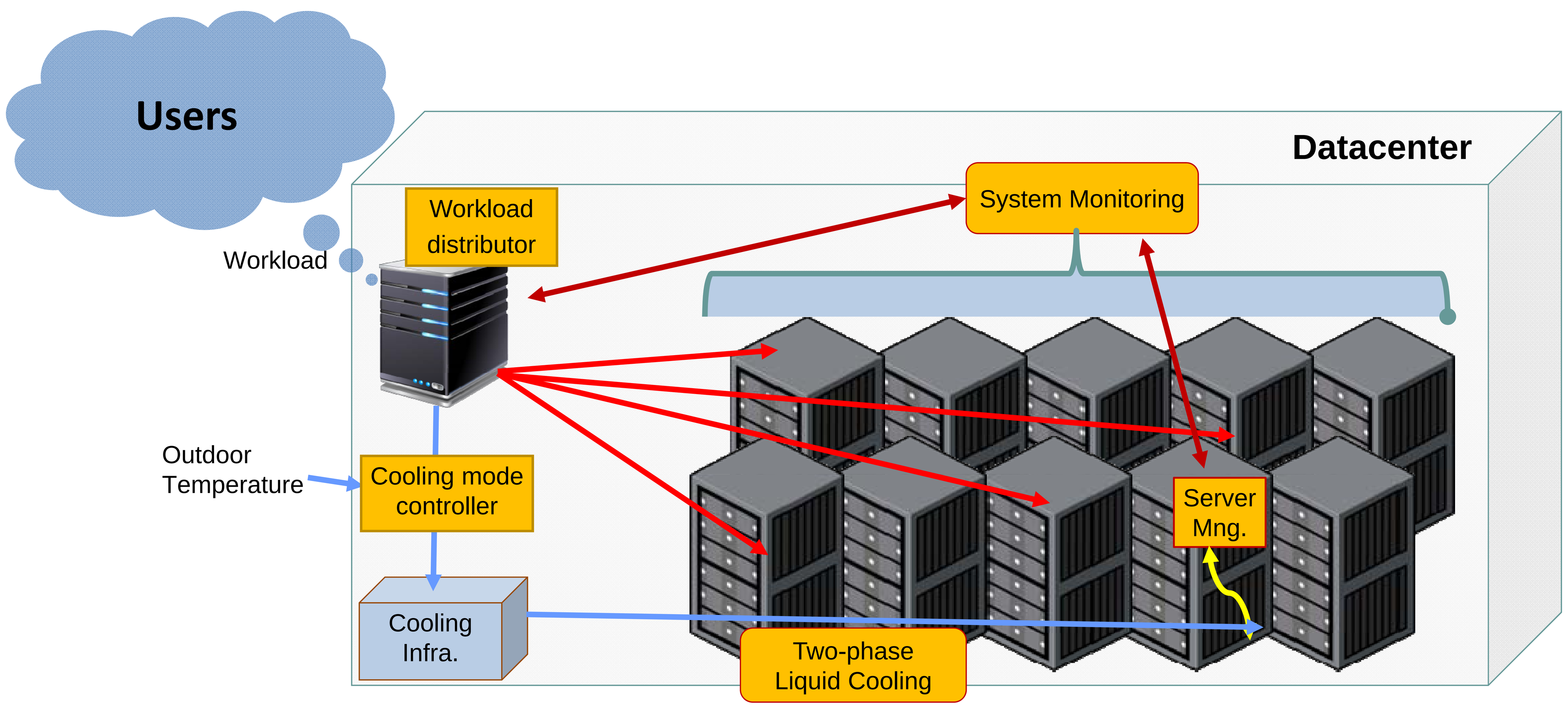




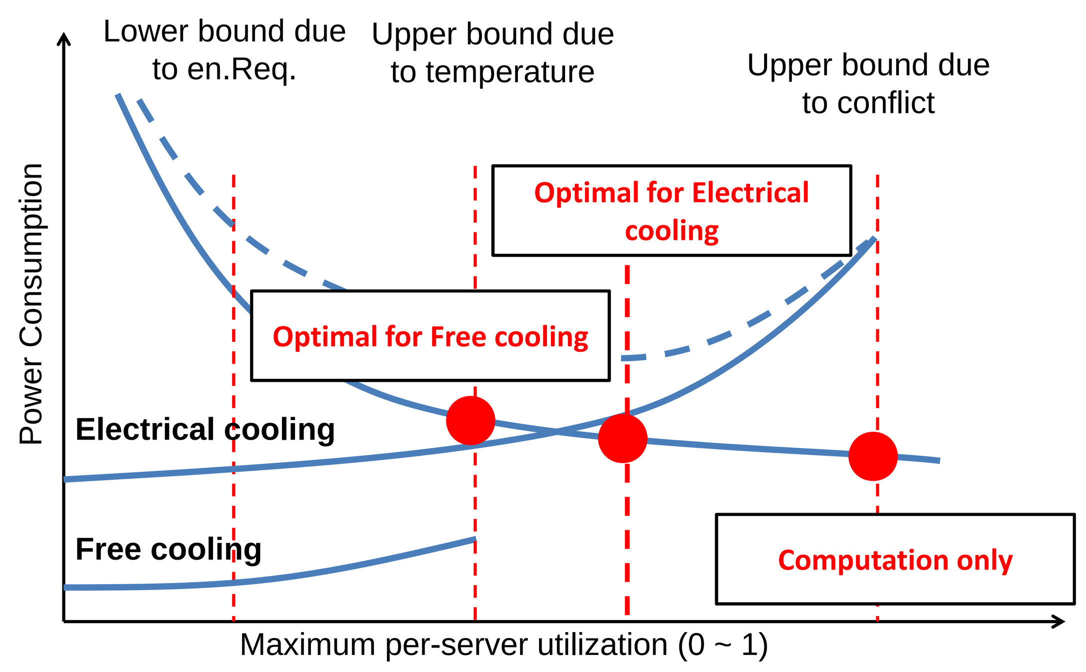
Power breakdown of datacenter

TRANSCEND Main Goals and Approach

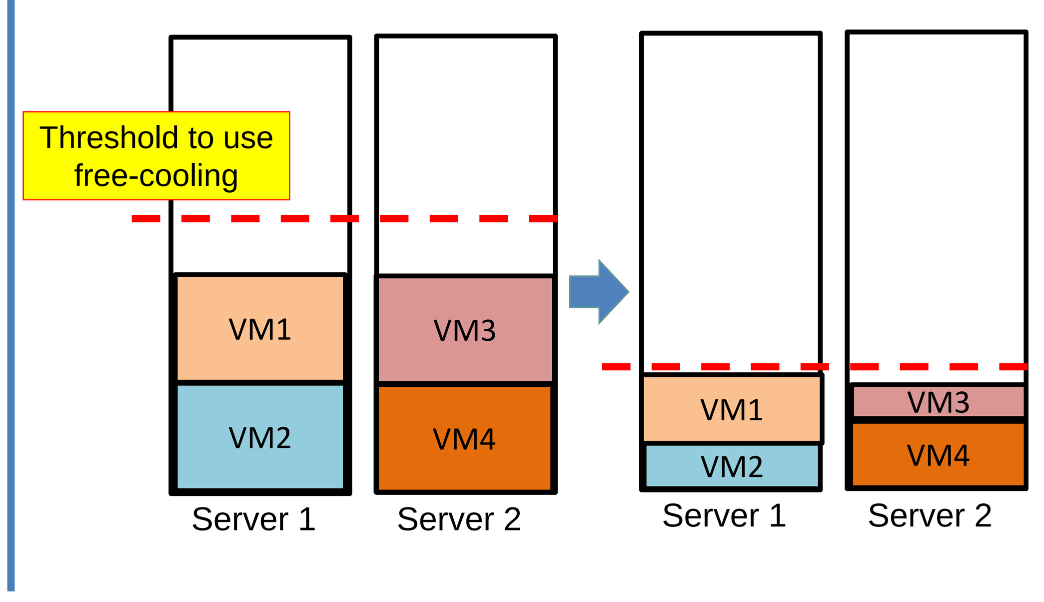
- Achieving Energy-Proportionality in Datacenters
- **Holistic Approach: HW-SW and infrastructure management**
  1. SLA Performance Guarantees
  2. Multi-level Software Management
  3. Innovative Cooling Infrastructure Design

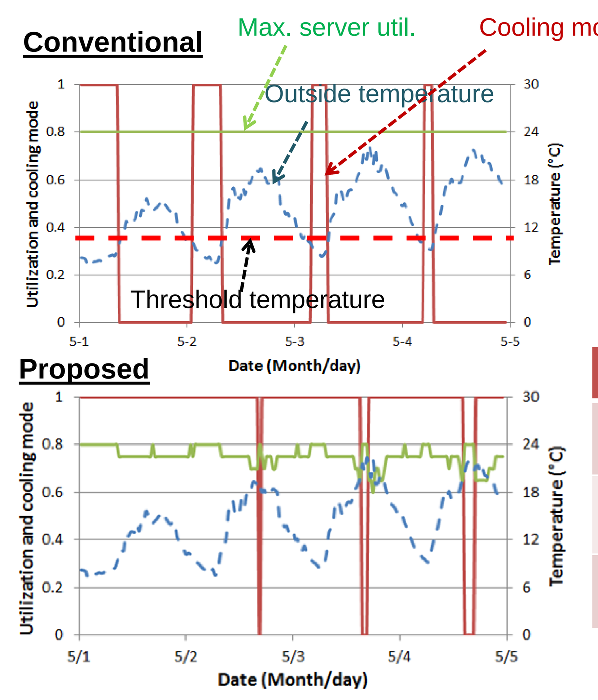


Cooling Power-Aware Optimization



Workload-Aware VM Allocation





Longer period of using free cooling with proposed method

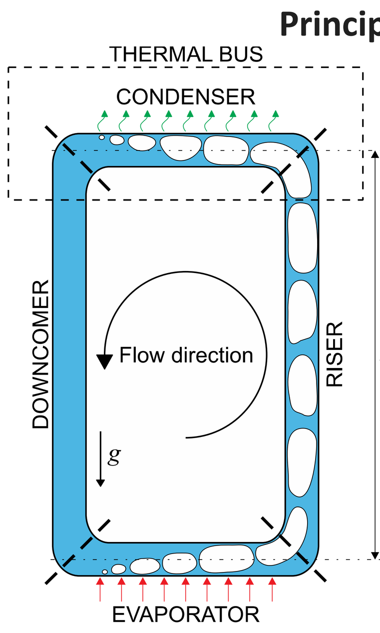
21.6% power savings

In Lausanne

Period	Conv.	Proposed
May	1.00	0.781
June	1.00	0.738
July	1.00	0.878

Innovative Cooling Infrastructure Design

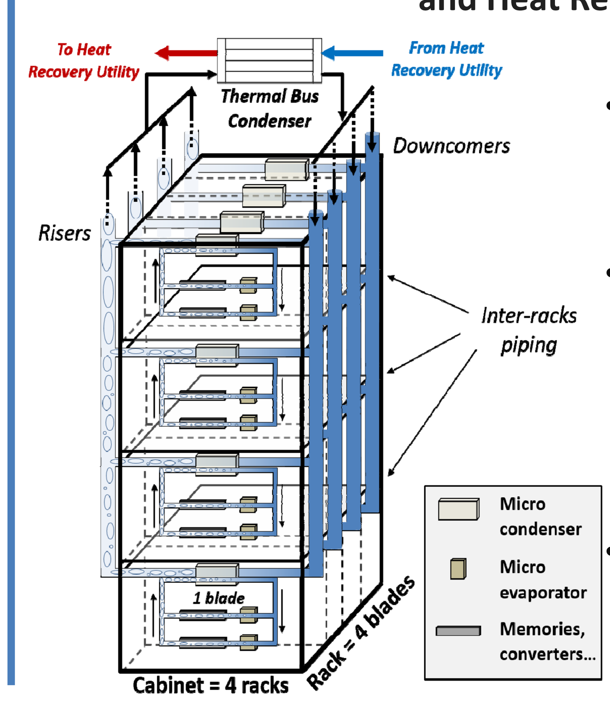
Principles of Thermosyphon Cooling Loop



- EVAPORATOR: Heat applied to the evaporator is the *driver* of the thermosyphon cooling loop.
- RISER: The generated vapor with a low density ρ_v ascends through the riser due to buoyancy.
- CONDENSER: Then, the vapor condenses in the condenser placed at the top.
- DOWNCOMER: Finally, the single-phase liquid with a density ρ_l higher than ρ_v flows downwards through the downcomer, closing the loop at the evaporator.

The density difference between single- and two-phase flow regimes induces a non-equilibrium state, in which a denser liquid tends to flow downwards (downcomer), compensating the less dense two-phase upflow in the riser.

Potential Blade/Cabinet Architecture/Cooling and Heat Recovery Systems



- Double-thermosyphon on-chip cooling implementation is anticipated.
- Dielectric refrigerant (R134a or new environmentally-friendly working fluids) with water flowing in a secondary loop will be considered.
- Heat recovered can be reused.

Simulation Results

Inputs:

- R134a as a working fluid at a saturation temperature of 60 °C (p_{sat} = 16.8 bar) and water in a secondary loop,
- R134a inlet–water outlet temperature difference of 15 K (approach temperature at the condenser),
- Cooling capacity of 200 W (~53 W/cm²).

#	D_{riser} [mm]	D_{down} [mm]	H [cm]	Micro-evaporator (ME) material, geometry, and orientation	Mass flow rate of R134a [kg/h]	Mass flux G_{ch} [kg/m²s]	Subcooling at the condenser outlet [K]	$T_{ME,junction}$ (maximum) [°C]	$x_{ME,out}$ [-]	CHF_{Ong} [W/cm²]
1	6	4	5	Aluminum, 2000 μm-high and 200 μm-wide in-line channels with 150 μm-wide fins, horizontal	6.08	70.4	19.07	74.9	0.64	68.8
2			10		11.77	136.2	14	77.2	0.28	110.5
3			15		15.66	181.3	11.8	77.7	0.2	135.7
4			20		18.54	214.6	8.9	78.5	0.18	153.2
5	7	5	5	Aluminum, 2000 μm-high and 200 μm-wide in-line channels with 150 μm-wide fins, vertical (flow up)	5.26	60.9	20.48	74.3	0.75	62
6			10		10.48	121.3	14.8	76.5	0.33	101.7
7			15		14.76	170.8	12.4	77.8	0.21	130
8			20		18.36	212.5	7.7	78	0.19	152.1

Simulations show that the passive thermosyphon cooling system is a potential technology to cool high heat flux microprocessors.

The heat flux simulated here is higher than ~40 W/cm², which relates to the processor of the SPARC T3-2 ORACLE server.

Conclusions

- The results of the project have shown a large impact on a number of areas related to computing systems and datacenters for industry:
  - **Density, performance, and efficiency:** Improved cooling system and management, as well as guaranteed responses and thermal guarantees for computing systems
  - **Cost reduction for continued growth of datacenter industry:** TRANSCEND results have proposed new hardware/software monitoring and cooling techniques to improve datacenter efficiency
  - **Technology leadership and continued growth:** Results applicable in the Swiss industry context