

SYSTEM DESIGN – A PROFESSIONAL APPROACH

Dr. Thomas Warschko, Shraddha Mahesh Thanki, Jennifer Draxinger, Sandra Fink

Eviden, Technical University of Deggendorf, Germany

EVIDEN

TECHNISCHE
HOCHSCHULE
DEGGENDORF THD

MOTIVATIONS

In an era where data is king, the fusion of High-Performance Computing (HPC), Artificial Intelligence (AI), and Big Data is revolutionizing our approach to computational challenges. This poster delves into the heart of this revolution, motivated by Two pivotal needs:

Sustainable Computing:

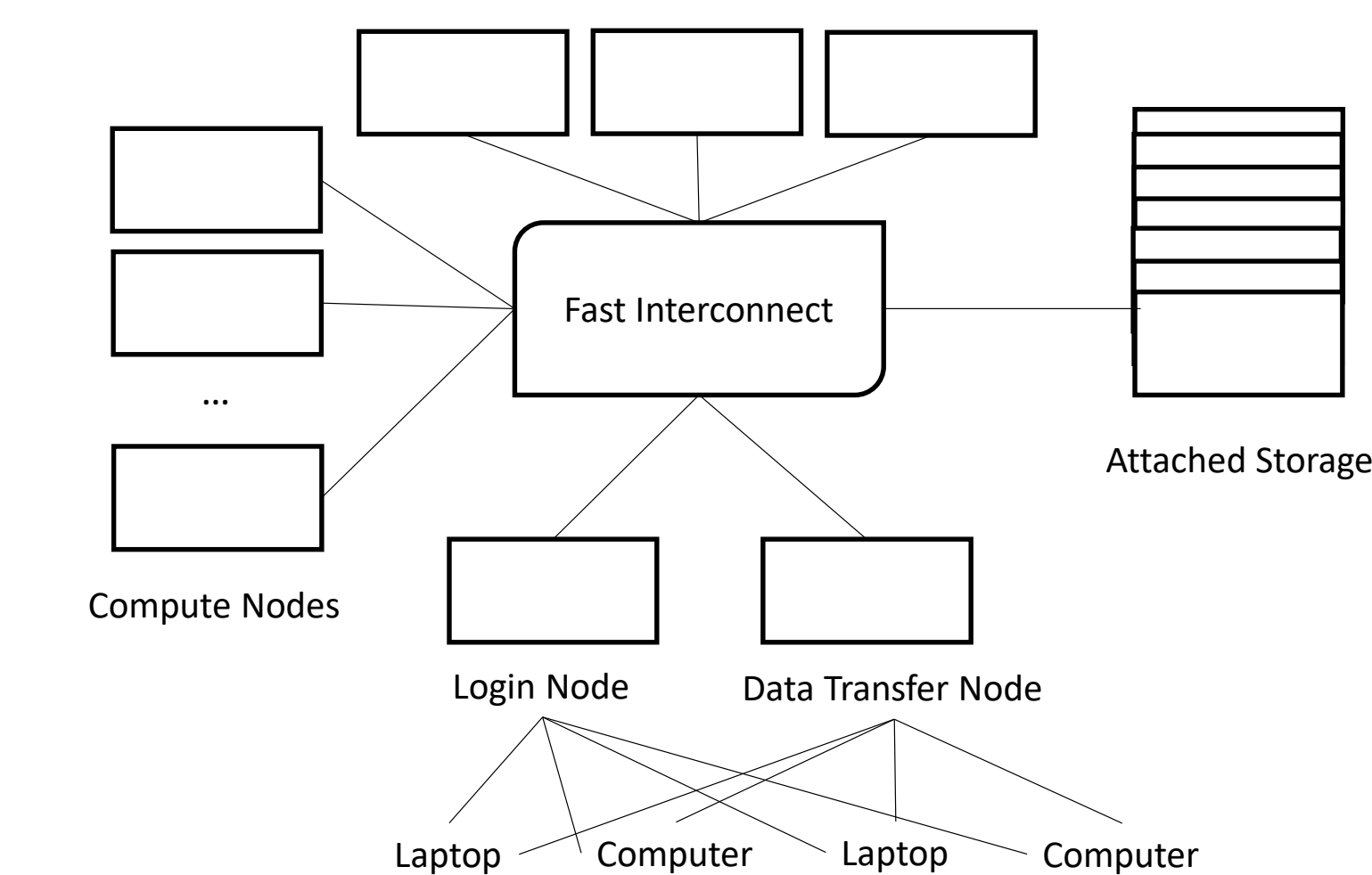
As the power of HPC systems grows, so does their energy footprint. Developing energy-efficient HPC solutions is crucial to reduce environmental impacts and operational costs, making sustainability a key driver of our research.

Practical Solutions for Complex Problems:

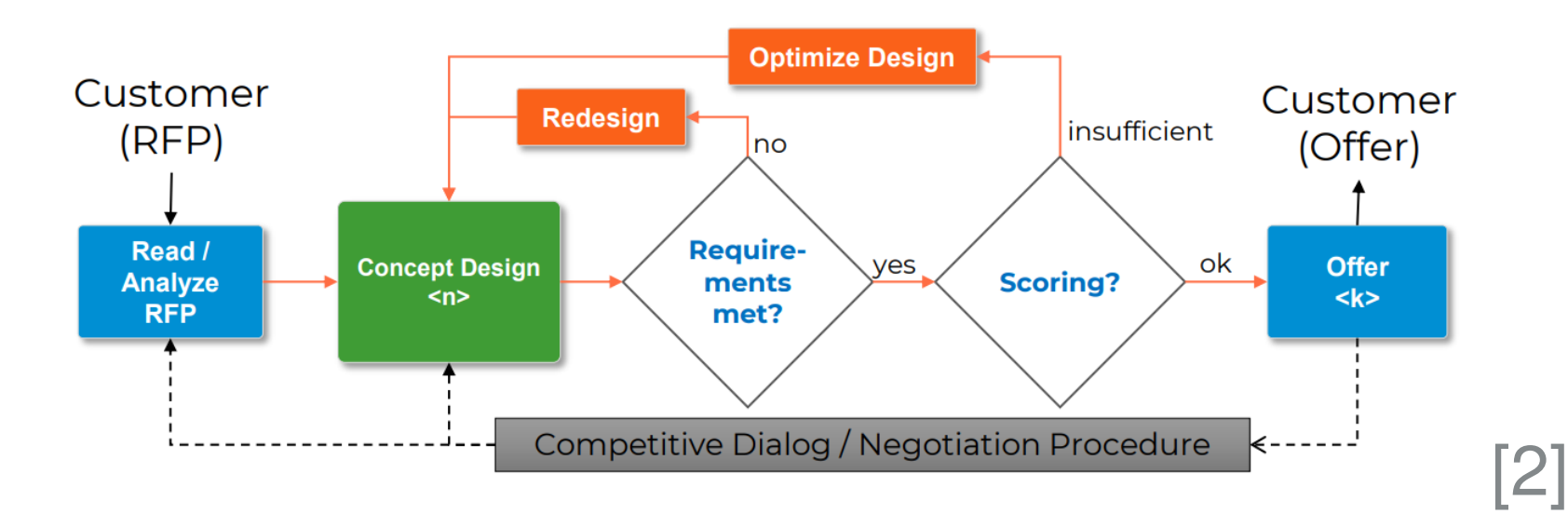
The complexity of modern computational problems in areas like genomics, climate modeling, and financial analytics requires advanced HPC systems. Our research is motivated by the need to build systems that can tackle these problems efficiently and effectively.

HPC CLUSTER ARCHITECTURE

- Nodes: The Building Blocks
- Interconnects: The Communication Backbone
- Storage solutions: The Data Repositories



PROFESSIONAL SYSTEM DESIGN PROCESS



System design is a complex, iterative process characterized by refinements and optimizations, driven by creativity, to arrive at the best possible solution.

References

- [1] NVIDIA. *Liquid-Cooled GPUs Steal the Show at Computex*. 2022. URL: <https://blogs.nvidia.com/blog/2022/05/23/liquid-cooled-gpus-computex/>.
[2] Thomas Warschko. *Personal Communication*. thomas.warschko@atos.net.

PERFORMANCE COMMITMENTS

Requirements:

In the realm of system design, customers seek specific performance levels or the ability to execute defined applications within set timeframes (ensemble runs). Estimating future technology's reliability is key, as these predictions face rigorous scrutiny during system acceptance, where failing to meet commitments often triggers penalties.

Issue: How to calculate the performance of an application on a future system?

PERFORMANCE PREDICTION & EXTRAPOLATION

$$T_{target}(f, BW, IB) = T_{CPU} + T_{BW} + T_{MPI+IO}$$

$$T_{CPU} = \alpha_{CPU} \frac{f_{ref}}{f_{target}} T_{ref} \left((1 - \epsilon_{AVX2}) + \epsilon_{AVX2} \frac{\eta_{op_ref}}{\eta_{op_target}} \right)$$

$$T_{BW} = \alpha_{BW} \frac{BW_{ref}}{BW_{target}} T_{ref}$$

$$T_{MPI+IO} = \alpha_{MPI+IO} T_{ref} \left((1 - \eta_{IB_BW}) + \eta_{IB_BW} \frac{IB_{ref}}{IB_{target}} \right)$$

[2]

f: processor clock speed

BW: per Core memory Bandwidth

IB: Interconnect technology

ref: reference platform (e.g., benchmarking system)

α_{CPU} : part of the code that depends on processor speed

α_{MEM} : part of the code that depends on memory bandwidth

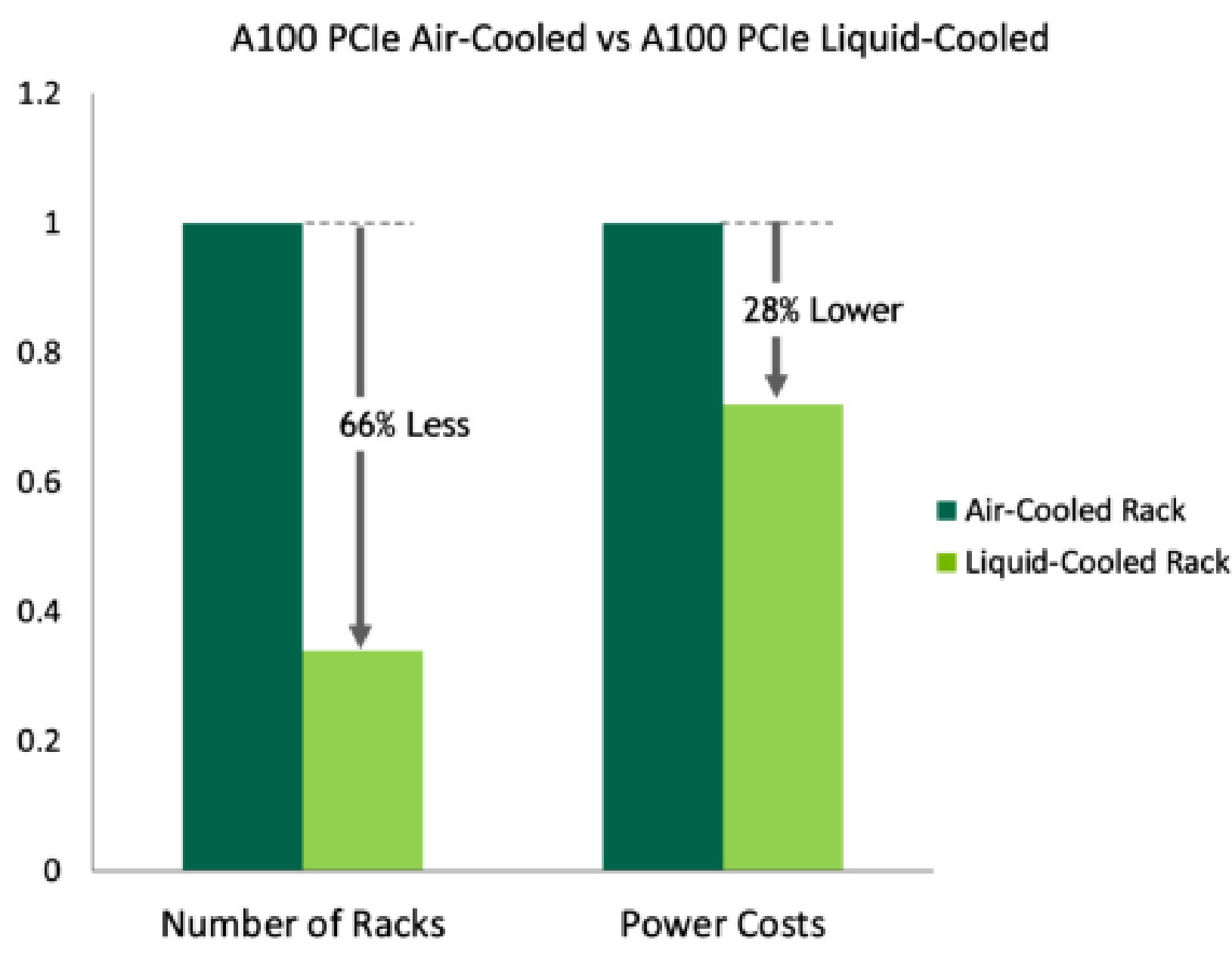
α_{MPI+IO} : part of the code that depends on communication speed and bandwidth

TOTAL COST OF OWNERSHIP (TCO)

- Water Cooling is more expensive (5% - 10%)
- Water Cooling needs infrastructure (water pipes in machine room)
- TCO saving is HUGE (up to 1M€) per Rack(96 nodes)!

Sample System (96 Nodes – 24 DoubleTwin)	Air Cooling	Water Cooled Door (cold water)	Direct Liquid Cooling (warm water)
Est. Purchase Price (Investment)	1.024.000 € (1000k + 12x 2k)	1.080.000 € + 5,5% (1000k + 4x 20k)	1.100.000 € + 7,4% (1000k + 100k)
#Racks (kW per Rack)	12x (12kW)	4x (35kW)	1x (140kW)
PUE	1,7	1,4	1,03
Average System Power	132 kW	140 kW	117 kW
Energy Cost per year (incl. cooling) 0.25€ per kWh	493.223 €	430.712 €	264.368 €
Total Cost over lifetime (5y)	3.490.115 €	3.233.558 € - 7,4%	2.421.840 € - 30,6%

CONCLUSION



[1]

66% less space

- 15kW Air-cooled rack vs.
- 30kW Liquid-cooled rack

Improved PUE

- 1.6 Air-Cooled Solution vs.
- 1.15 Liquid-Cooled Solution

28% less power

Catalyzing Efficiency: Liquid-cooled HPC systems offer a transformative 66% reduction in space requirements and a substantial 28% decrease in power consumption.

In a 15kW air-cooled vs. 30kW liquid-cooled rack comparison,

PUE impressively improves from 1.6 to 1.15, highlighting liquid cooling's pivotal role in sustainable, energy-efficient HPC operations and setting a pioneering standard for future designs.