



Advanced Control for Data Center Cooling

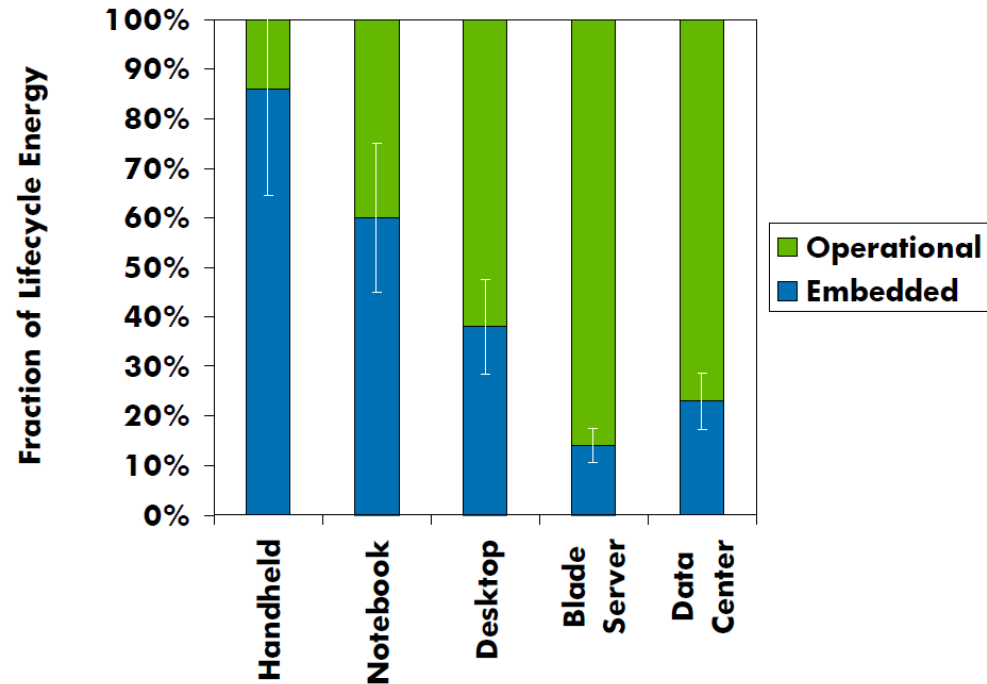
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Motivation

- Recall the problem of data center energy consumption
- HVAC comprises half of energy consumption in US
- IT sector is responsible for 2% of carbon emissions



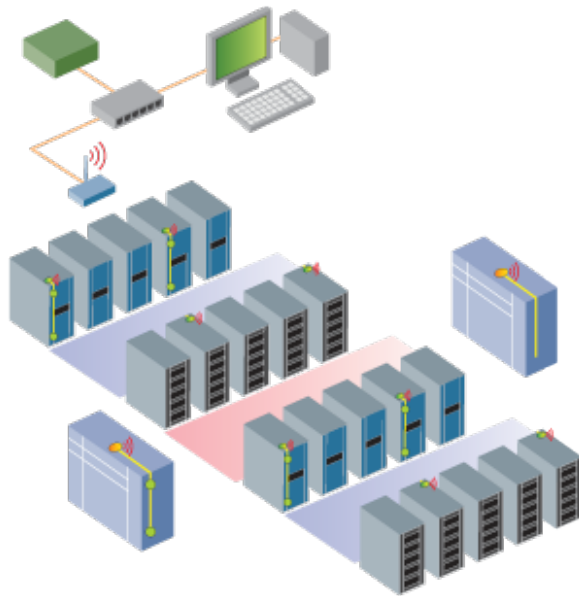
Source: Manish Marwah, EE392N presentation

Business Feasibility

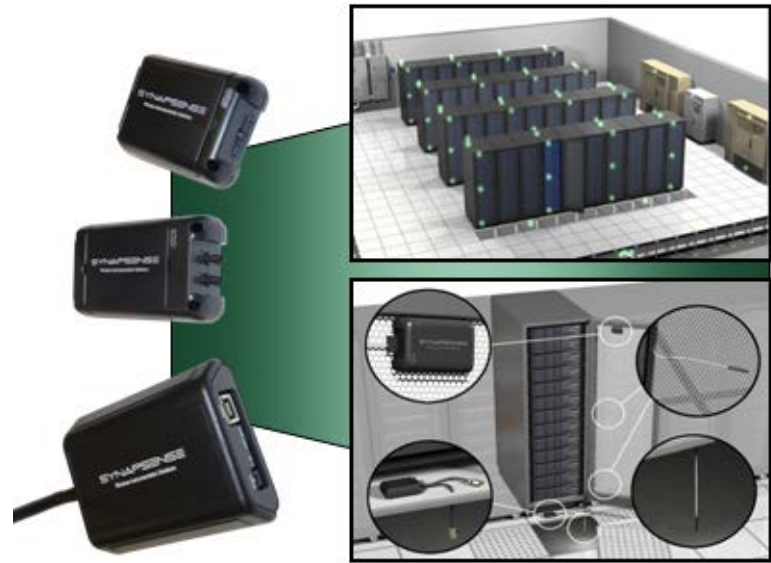
- Amount of savings is great
- Several companies offer data center efficiency packages
 - Synapsense
 - Vigilent
- These companies can provide a portal for new research to be utilized

Technical Feasibility

- The amount of available data is great
- Data center optimization companies use control strategies that are primitive (PID, neural network) compared to the
 - Sensors
 - Wireless communication protocols



Source: Vigilent

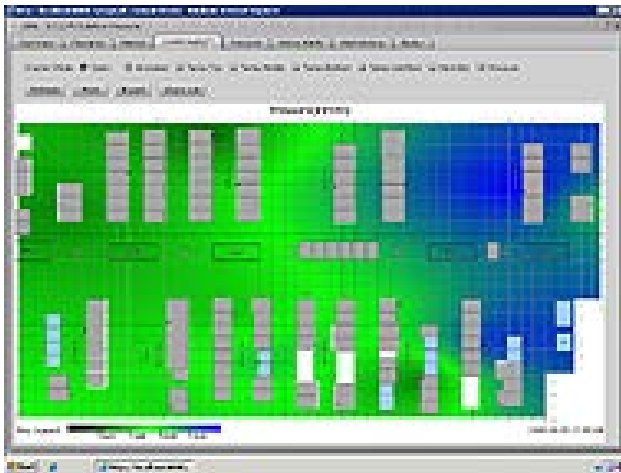


Source: Synapsense

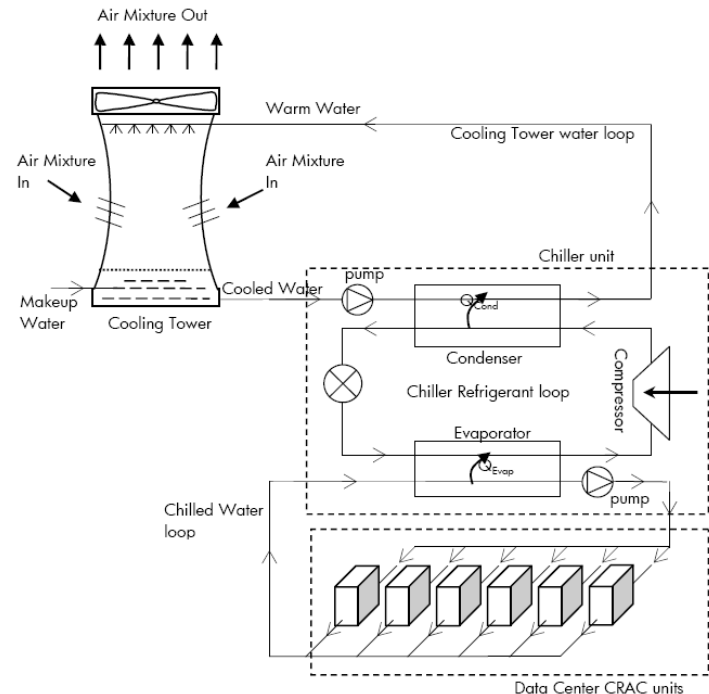
Academic Feasibility

- Decisions (and data?) are hybrid in nature
 - “Turn on compressor” or “Set cooling tower fan to ___”
- Complex system(s) involved:
 - Air conditioners (CRAHs) are (very) nonlinear
 - The data center itself is a large 3D fluid flow problem

$$COP_{\text{cooling}} = \frac{\Delta Q_{\text{cool}}}{\Delta A} \leq \frac{T_{\text{cool}}}{T_{\text{hot}} - T_{\text{cool}}}$$



Source: Synapsense



Source: Manish Marwah, EE392N presentation

Advanced Control: Relevant?

- Some of the usual barriers for advanced control:
 - Increased efficiency is not very important
 - Not broken => don't fix it
 - The control algorithm must be easily understandable
 - Control designer's effort must be scalable
- There is active research in modeling/control for commercial buildings
 - Distributed model predictive control
 - Data centers are much more
 - Predictable
 - Higher energy density => better ROI
 - Companies already provide turn-key solutions for data centers

Additional References

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- Amer. Contr. Conf., 2010. [3] Technology Roadmap, Energy-efficient Buildings: Heating and Cooling Equipment, IEA, 2011.
- F. Oldewurtel, et al, “Increasing Energy Efficiency in Building Climate Control using Weather Forecasts and Model Predictive Control”, *Clima - RHEVA World Cong.*, 2010.
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