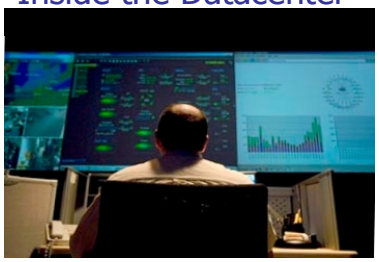
Lecture 23
Inside the Datacenter



Some slides from Tom Wenisch, James Hamilton

Administration

- Alpha Release
  - If I received your URL by 6pm on Friday, you should have received feedback
  - If I received it later, you *may* have already received feedback.
- Midterms almost done; coming Wed.
- Final Projects due in 1 week

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The Datacenter

- Where is the Web?

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The Datacenter

- Those machines have to go someplace!

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The Rack

- Fill it with machines, hook them up to the network, you're ready to go

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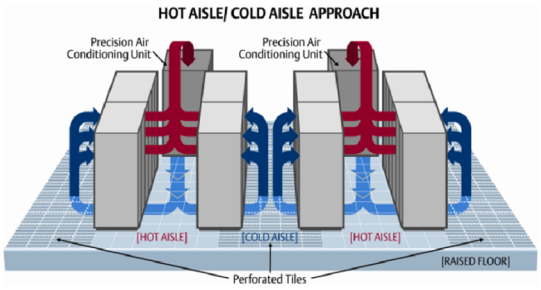
Cooling the datacenter



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Services

- Datacenters may provide:
  - Physical Security
  - Good environment
  - Network access
  - Power resources
  - Weather hardening

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Services

Security		
Environment		
Network		
Power		
Weather hardening		

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Services

Security	Biometric scan, locked doors	
Environment	A/C!	
Network	Multiple Physical Taps	
Power	Transformers	
Weather hardening	Roof!	

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Services

Security	Biometric scan, locked doors	Guard, cards, faraday cages
Environment	A/C!	
Network	Multiple Physical Taps	Multiple Networks
Power	Transformers	Diesel, batteries, flywheels
Weather hardening	Roof!	Earthquake resistance

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Datacenter Economics

- Some datacenters run by a single entity
  - Google, Microsoft, Univ of Michigan
- Others rent space to smaller customers
- Cost of running datacenter combo of:
  - Amortized costs of the building (15 yrs)
  - Amortized costs of electrical equipment
  - Amortized costs of servers (3 yrs)
  - Power, Bandwidth, Labor
- When you rent space, you pay for:
  - Space, power, bandwidth, maybe labor

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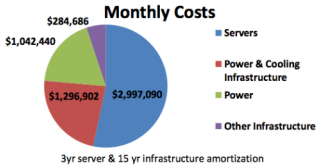
Power & Related Costs

- Some numbers from James Hamilton…
  - Facility: ~$200M for 15MW facility
  - Servers: ~$2k/ea, about 50k of them
  - Power draw at 30% util: 80%
  - Commercial power: 0.07/kWhr



- Note: power & related hardware costs high
- Servers going down in price; power flat or up

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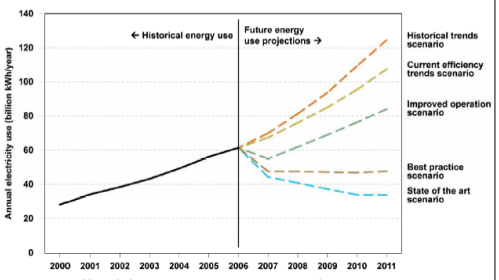
Datacenter Energy Growth



- Installed base grows 11%/year
- By next year, 2.5% of all US energy use

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Fully-burdened cost of power

- Infrastructure cost/watt
  - Using 15-year amort, 5% interest
  - $1.28/W/yr
- Energy cost of watt using 0.07 Kwhr
  - $0.83/W/yr
- Full cost: $2.11/W/hr

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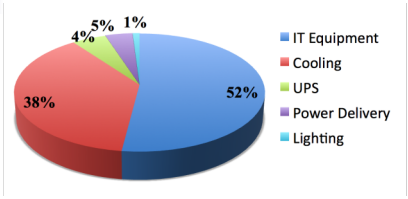
Heat



- Servers account for barely half of power
  - 1W of cooling per 1.5W of IT load
- Managing energy consumption means, to a large extent, managing heat

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Key Sources of Inefficiency

- Energy wasted by idle systems
  - Up to 75% idleness; but idle power ~60% of peak
- Inefficient cool air distribution
  - Hot exhaust recirculation halves cooling efficiency
- Power conversion losses
  - 4+ conversions; some under 70% efficiency
- Poor server performance per watt
  - Embedded sys. up to 5*x* better on Web 2.0 apps [Lim '08]

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Datacenter Efficiency

- Power Usage Effectiveness (PUE)
  - Total Facility Power / IT Equipment Power
  - For each watt, how much to computing?
  - 1.0 means no extra cost at all
  - Google claims 1.16
  - The Michigan datacenter we saw is 2.5
- Data Center Infrastructure Efficiency
  - IT Power / Facility Power * 100%

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Current Challenges

- Whole datacenter must be optimized, not just filled with more efficient computers
  - CPUs only account for 12% of energy!
- Challenges:
  - Power infrastructure very inefficient
  - Utilization & poor energy-proportionality
  - Cooling efficiency

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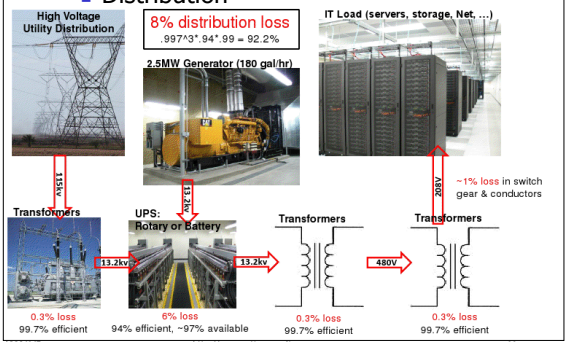
Power Infrastructure

- Distribution



Power Infrastructure

- Solutions:
  - Avoid unnecessary transformations on motherboard; use high-quality parts
  - Avoid transformations & UPS
  - Increase efficiency of conversions
  - Bring high voltage close to machines
  - Others
- In particular:
  - Avoid generator/battery spending by using many smaller distributed datacenters

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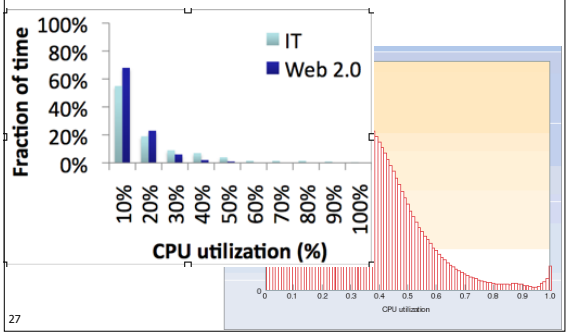
Utilization

- Machines usually very poorly utilized…



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Utilization

- Why so poorly utilized?
  - Work spread over many machines for robustness, data safety
  - Natural variance in load means most times will not be peak
    - Is it ever possible to do more work during off-peak times to reduce work during peak times?
    - Often, no
  - Server-class machines often mismatched to Web workloads
  - Many background tasks mean machines never completely idle

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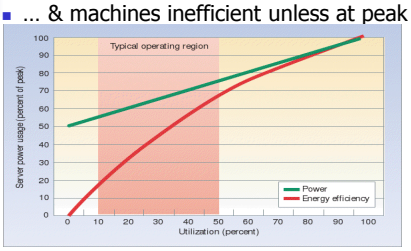
Energy-Proportionality

- … & machines inefficient unless at peak



- Why?

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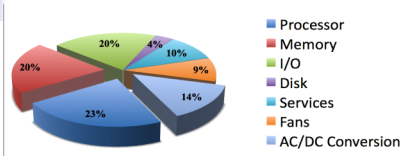
Energy-Proportionality



- No one component dominates
- CPU has better dynamic range than others, esp. on embedded processors
- Other components only Off or On
  - Or for networking, just On!
- What's wrong with proportionality?

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Energy-Proportionality

- Solutions:
  - Better dynamic range from DRAM, disks, network
  - Build systems that are low peak-perf but high-throughput per $. Uses embedded & slower processors.

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Cooling Efficiency

- Solution: Raise the set point
  - May require manufacturers to allow machines to run hotter

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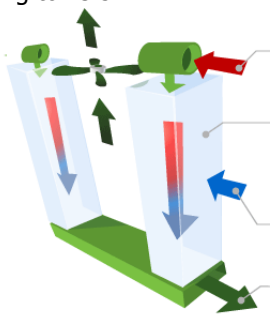
Cooling Efficiency

- Cooling towers



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Cooling Efficiency

- "Air-side economization"

- Microsoft found that servers are far sturdier than commonly believed
- 100% uptime for 8 months
  - Rain dripped on machines; fence blew onto rack

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Cooling Efficiency

- Other approaches
  - Better airflow control
  - Reclaim waste heat (maybe enough for PUE < 1.0)

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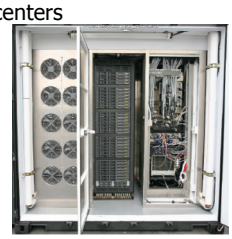
Wild Idea

- Containerized datacenters



- Faster to deploy, as all services built-in
- Build & pay for facility piece-by-piece
- Less human-habitable space, so A/C more efficient
- Build off-site, then ship to destination

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Other Challenges

- Energy is an extremely important issue, but not the only one
  - Datacenters use lots of H20 for cooling
  - Sol'n: reduce electricity consumption & use recycled & lightly-dirty H20
- Vibration from equipment
  - <video>

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Video: Container Datacenter

- Google built a datacenter with many of the ideas found in this lecture
  - <video>

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Conclusion

- Once a closet for machines, the datacenter must be optimized as a whole
- It is a "warehouse-scale computer"

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